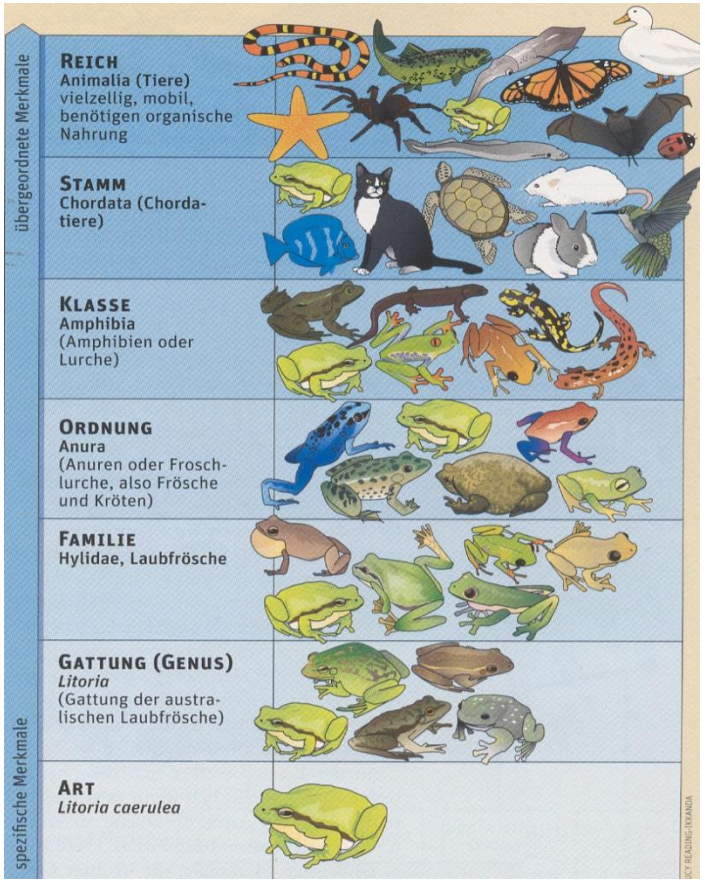
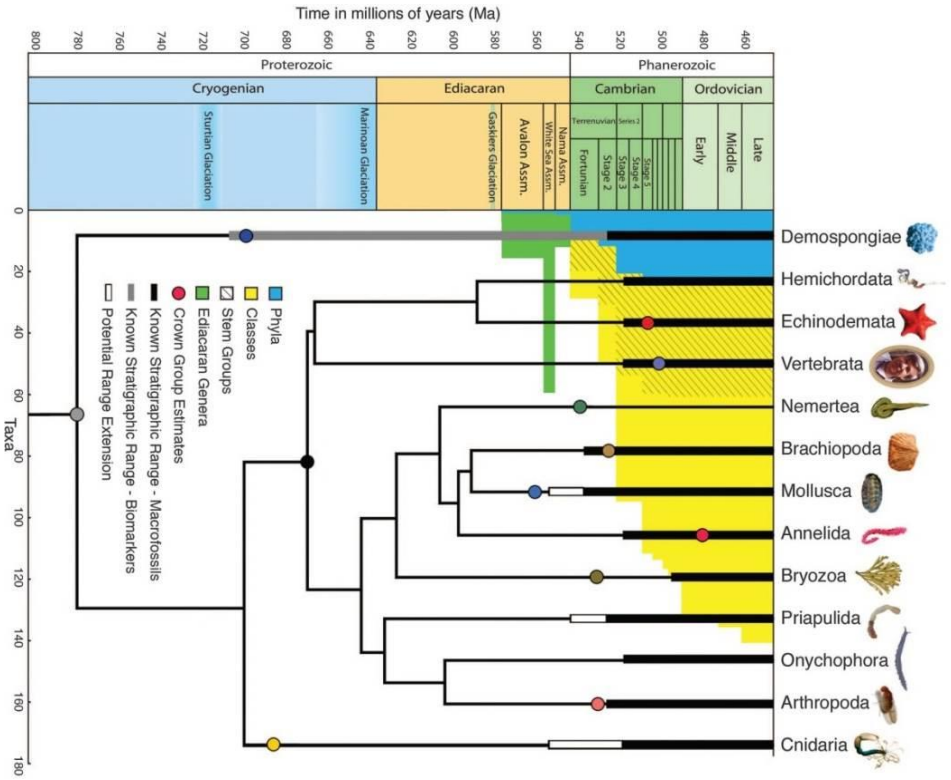
Systematische Zoologie
– oder Zoologische Systematik



- **eine Einführung ins Reich der Tiere**

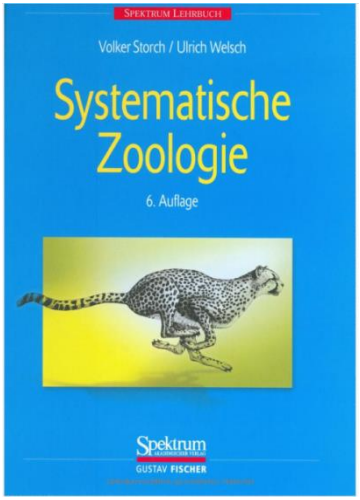


Matthias Glaubrecht

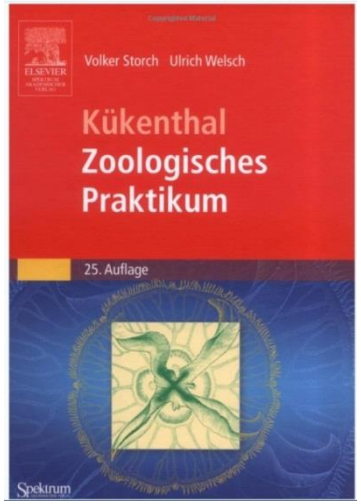
CeNak
Centrum für Naturkunde

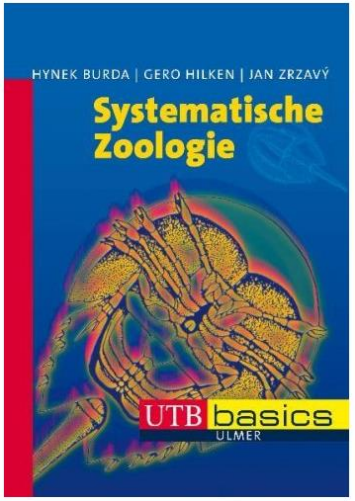
Einführung

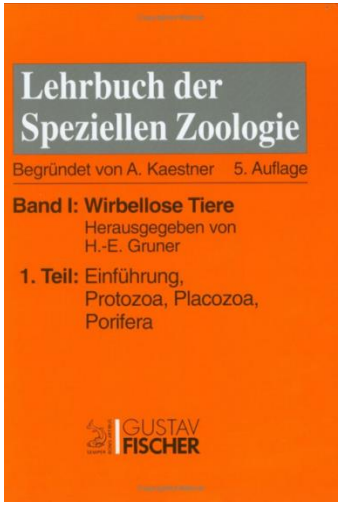
- **Systematische Zoologie – Lehrbücher**



Storch, V. & Welsch, U. 2004.
Systematische Zoologie.
Heidelberg (Spektrum).

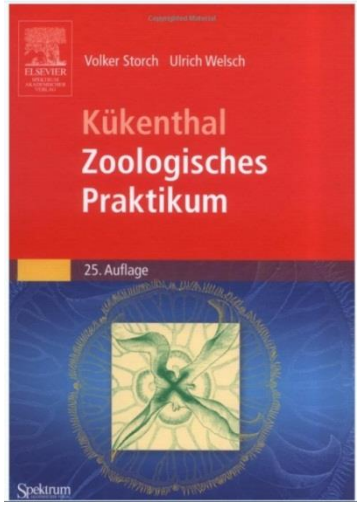






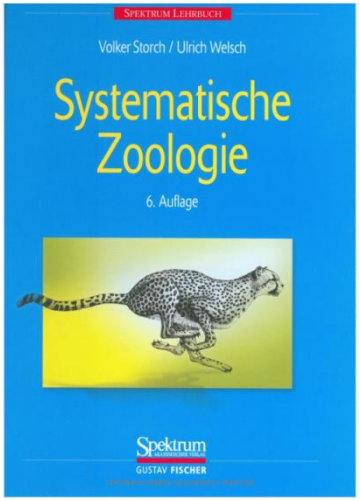
Einführung

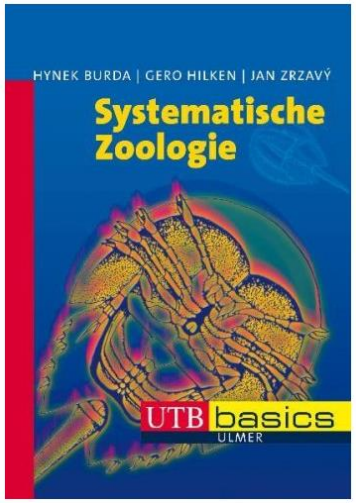
- **Systematische Zoologie – Lehrbücher**

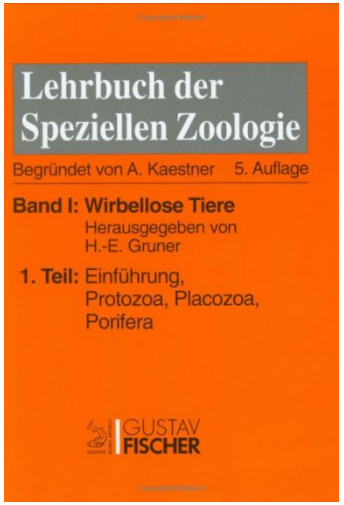


Storch, V. & Welsch, U. 2009.
Kükenthal Zoologisches
Praktikum.
Heidelberg (Spektrum).

Als PDF im Uninetz verfügbar!





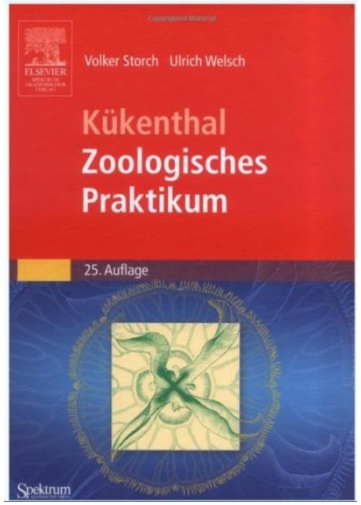


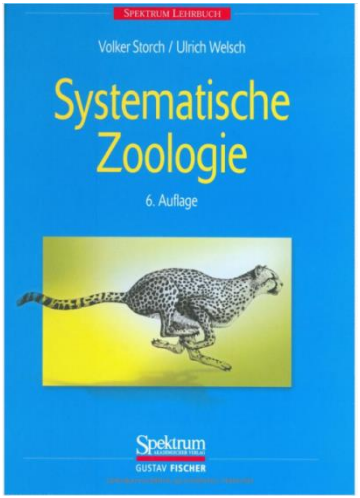
Einführung

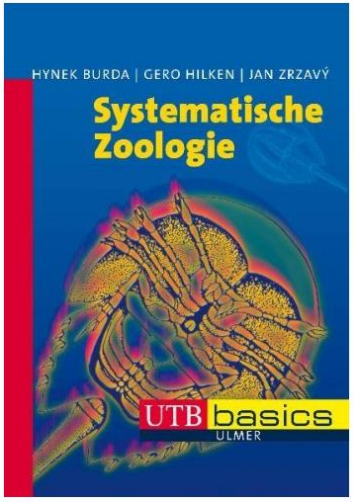
- **Systematische Zoologie – Lehrbücher**

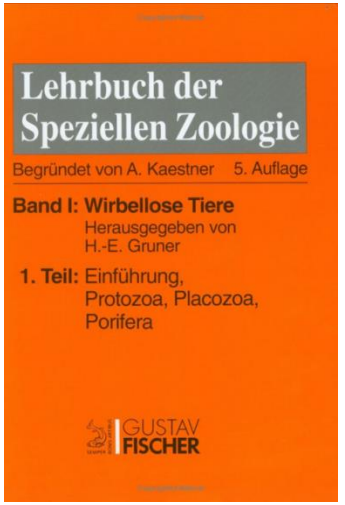
Westheide, W. & Rieger, G. 2013.
Spezielle Zoologie. Teil 1: Einzeller und Wirbellose Tiere. Heidelberg (Spektrum).

Westheide, W. & Rieger, G. 2010.
Spezielle Zoologie. Teil 2: Wirbel- oder Schädeltiere. Heidelberg (Spektrum).



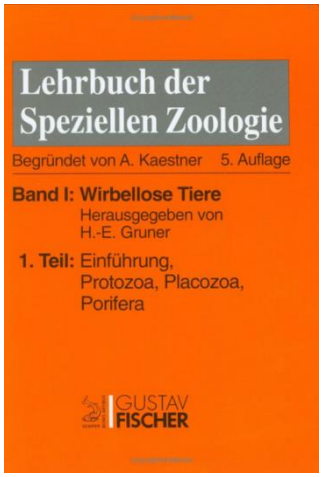




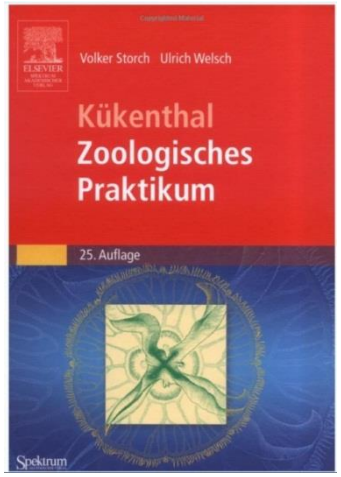


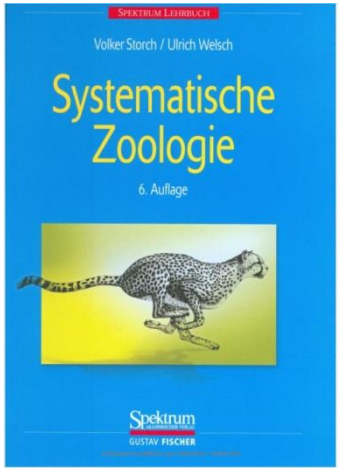
Einführung

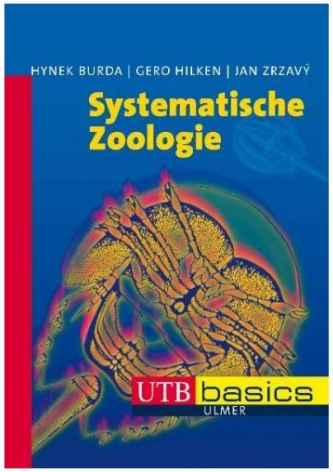
- **Systematische Zoologie – Lehrbücher**



Kaestner, A. 1991-2003. Lehrbuch der Speziellen Zoologie. Heidelberg (Spektrum).

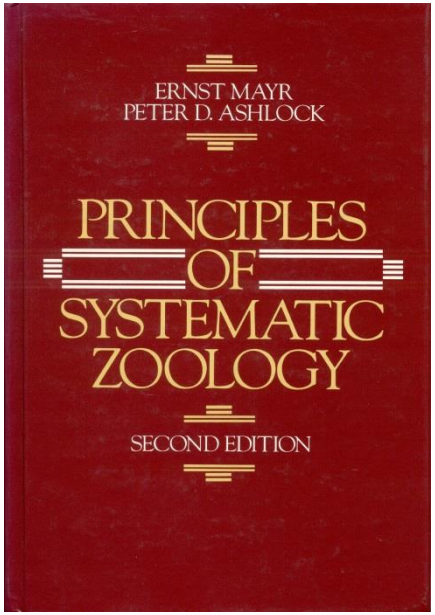




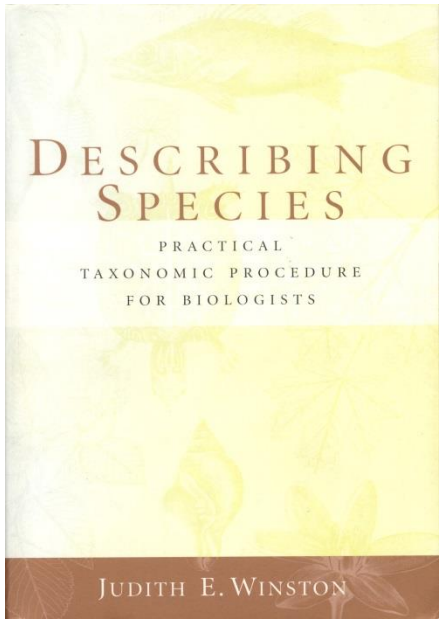


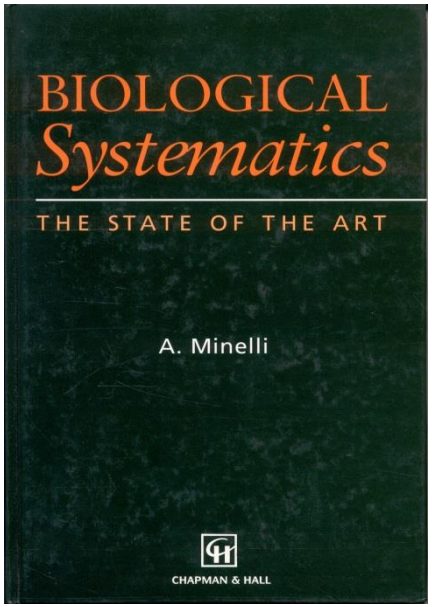
Systematik – Prinzipien und Praxis

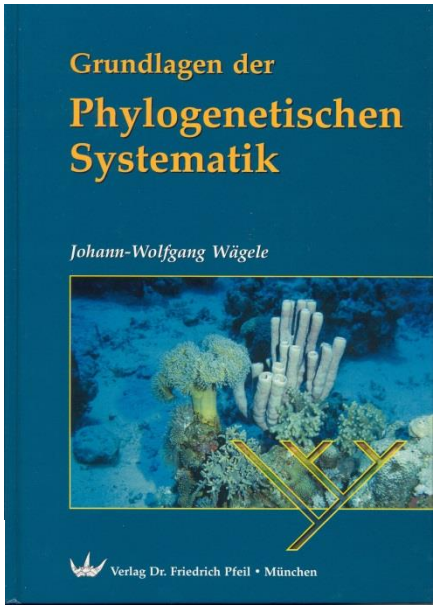
- **eine Auswahl an Empfehlungen**



- **Wie man Arten beschreibt & benennt**

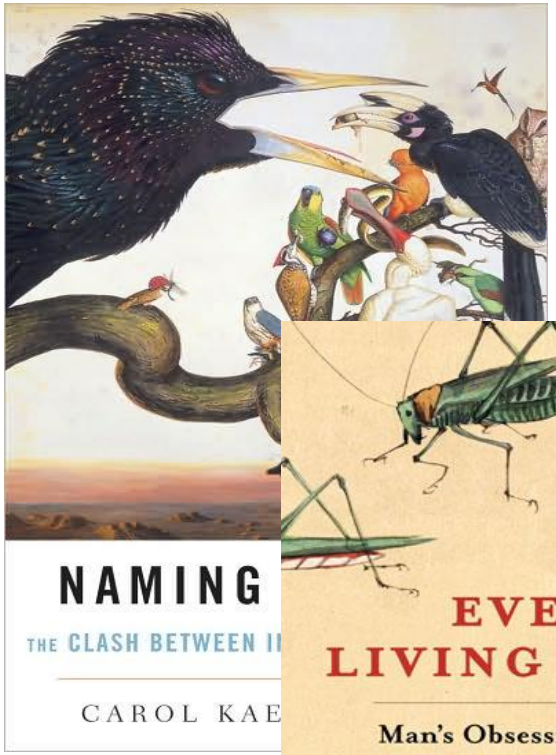


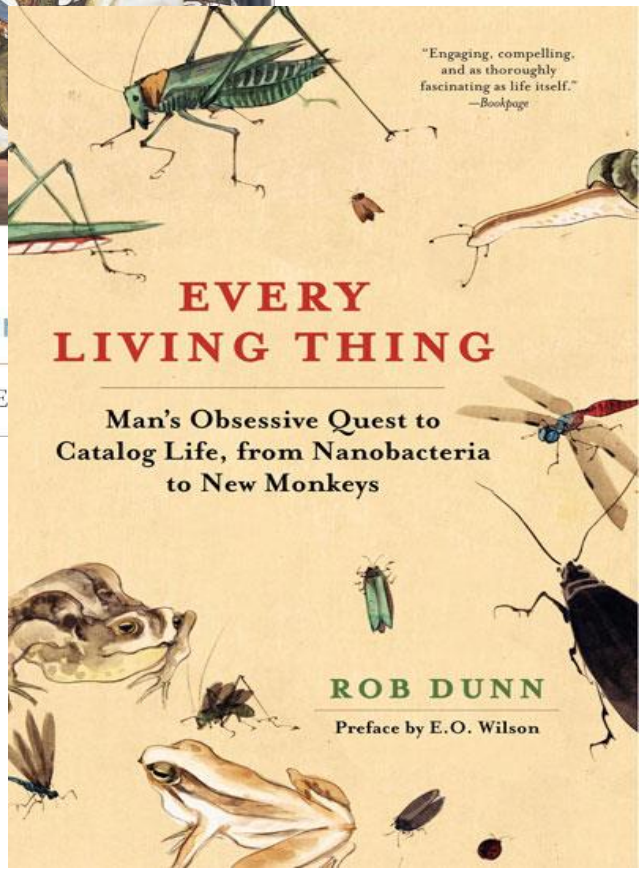


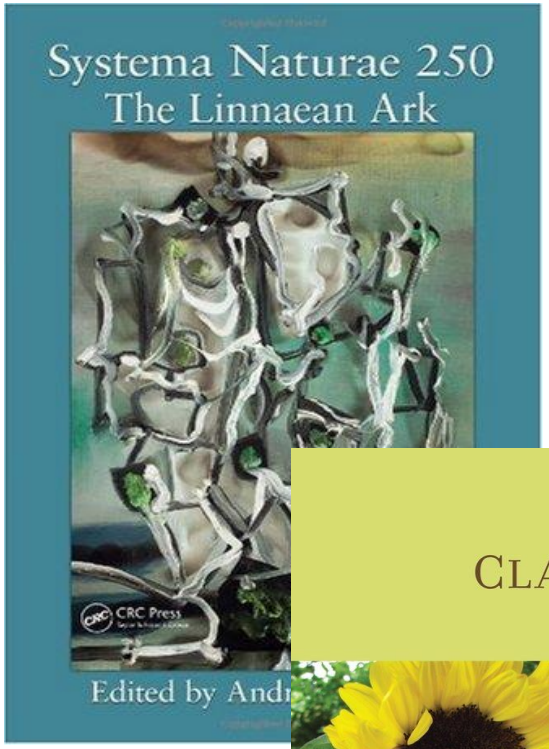


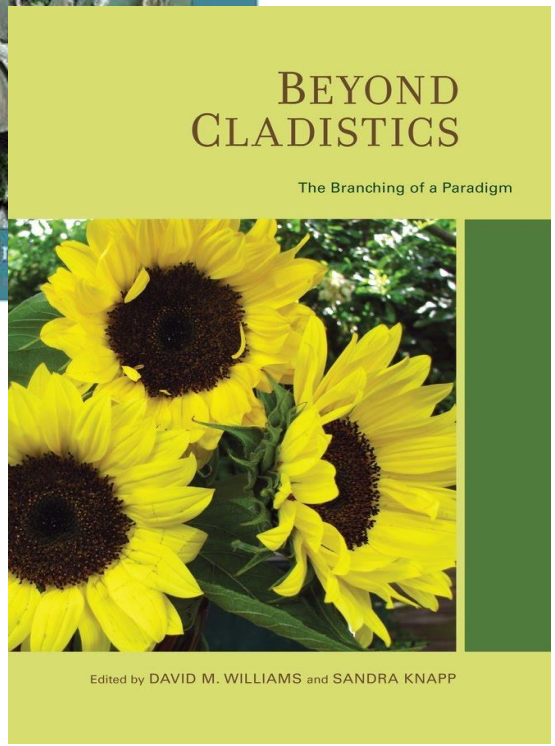
- **Wie man phylogenetische Systematik betreibt**

Naming nature – cataloguing life

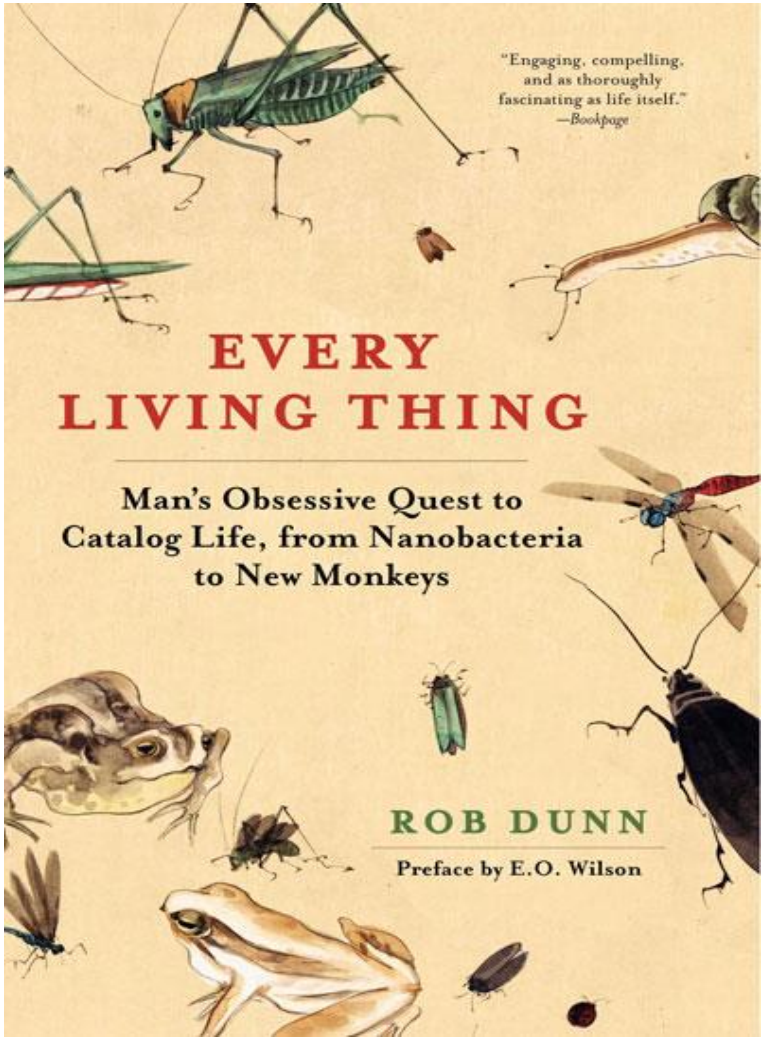




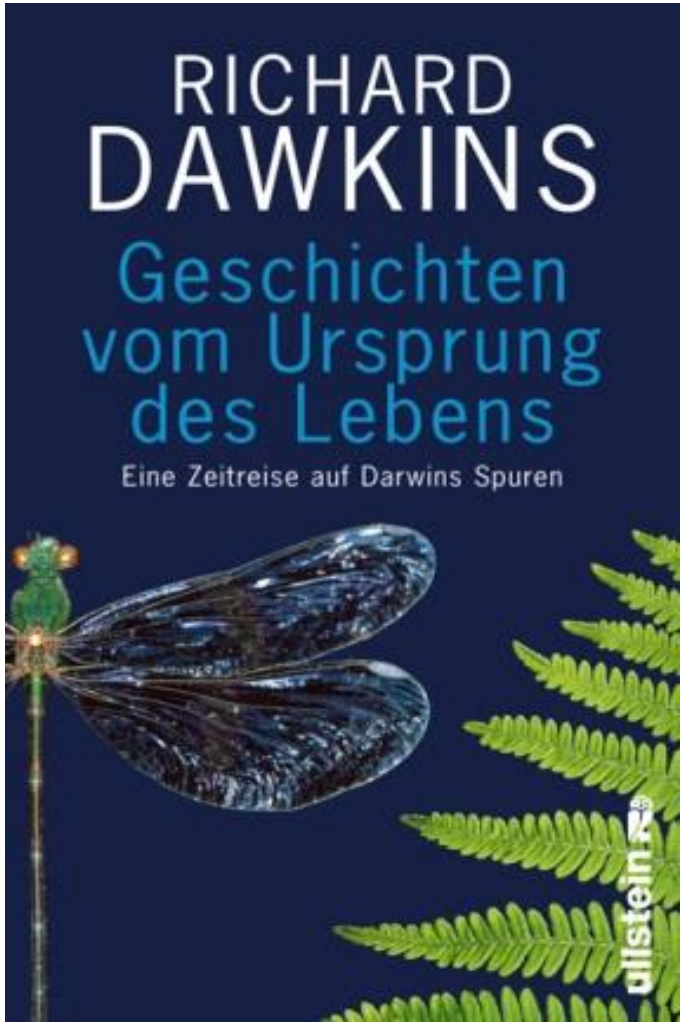




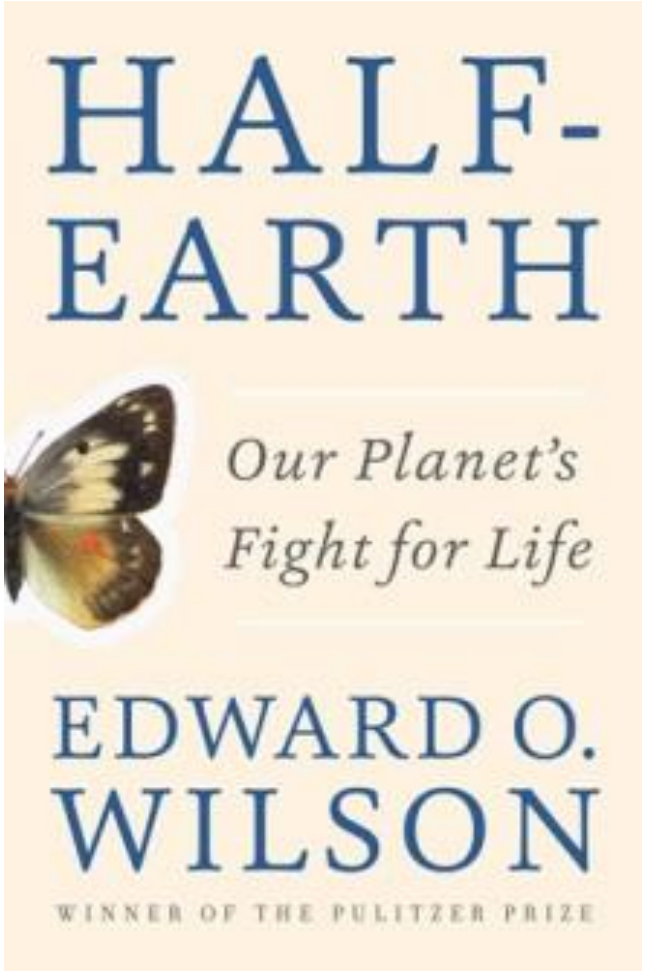
Naming nature – cataloguing life



Eine Auswahl & Empfehlung



- **Pilger- / Zeitreise zum Anfang des Lebens**

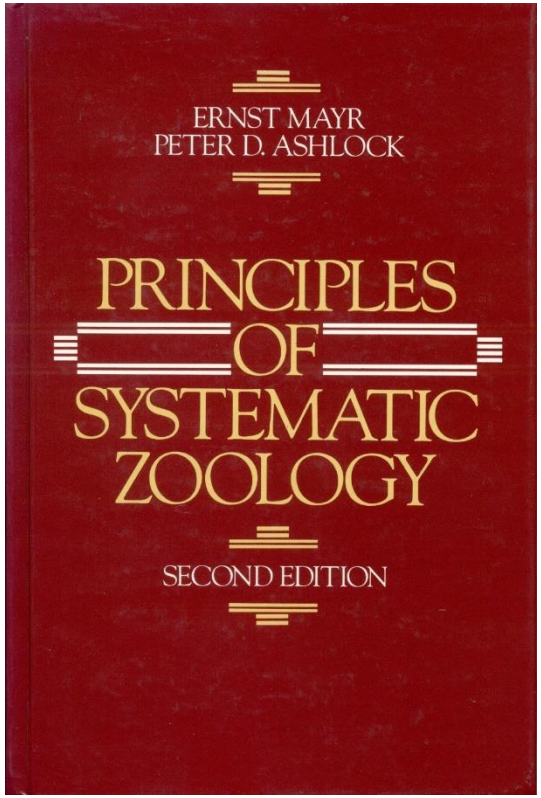


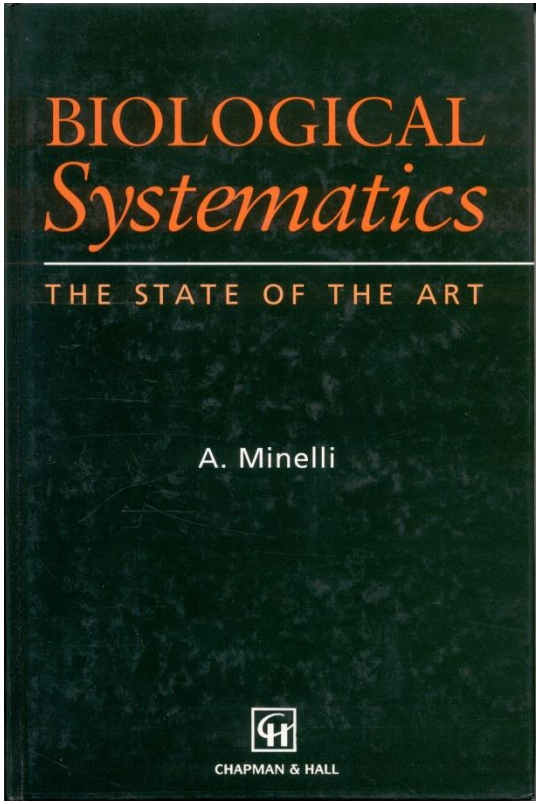
- **Wie wir die Artenvielfalt erhalten (könnten)**

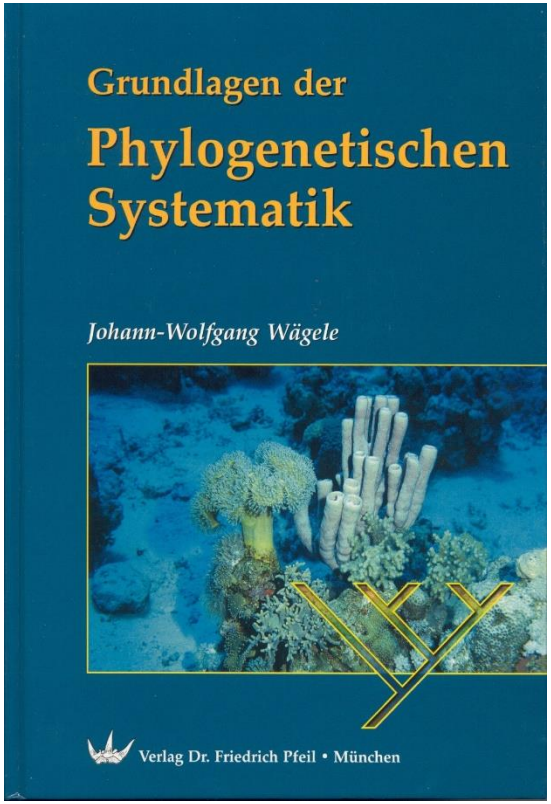
Zoologische Systematik - Zur Methode einer "alten" Disziplin

„Ob eine Disziplin zur ‚modernen' Biologie gehört, hängt nicht von ihrem Alter ab, sondern davon, ob sie sich theoretisch und methodisch auf der Höhe der Zeit befindet."

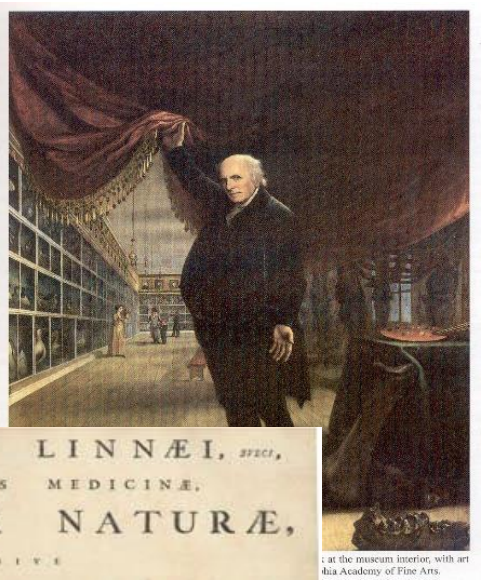
(R. Löther, 1972)







Zoologische Systematik – Zur Einführung



- **I - Der Blick hinter die Kulissen des CeNak**

  Was hat ein Museum mit Systematik zu tun ?

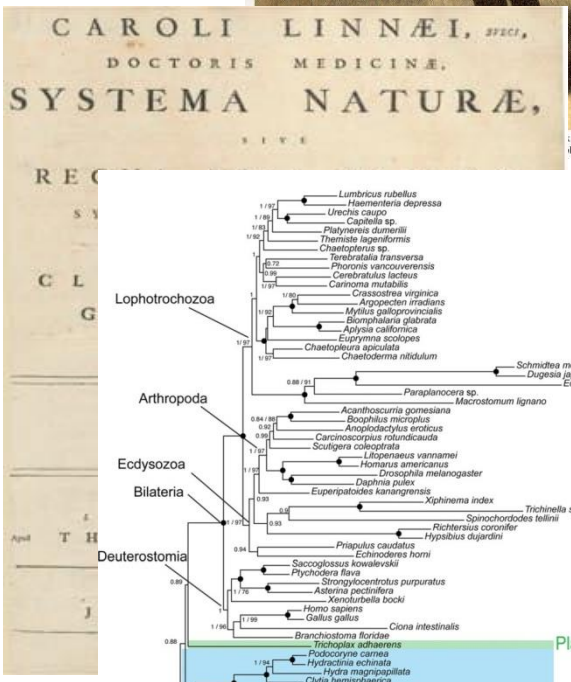
- **II - Grundbegriffe & Geschichte**

  Was ist eigentlich Systematik ?

  Wie geht das; warum betreiben wir sie ?

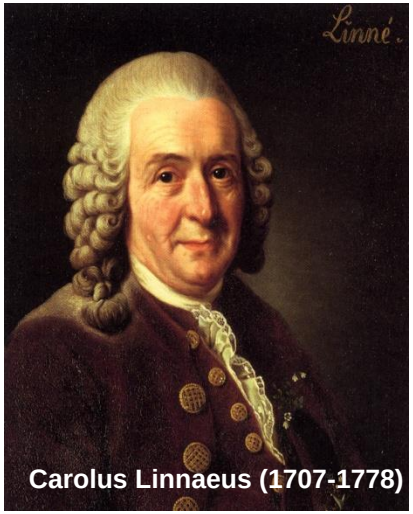
- **III – Systematische Zoologie**

  Das System der Tiere



Taxonomie und Biosystematik

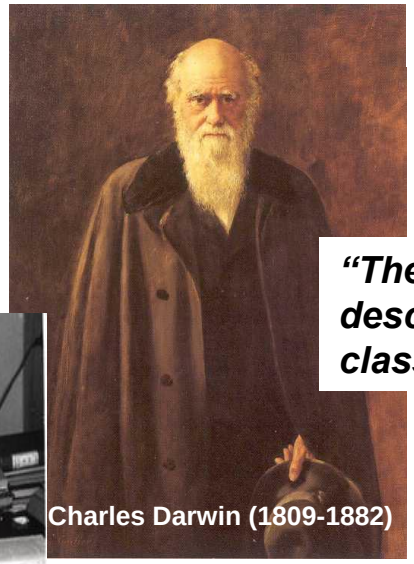
Von der ersten "*bioinformation crisis" zur* phylogenetischen Klassifikation



Carolus Linnaeus (1707-1778)

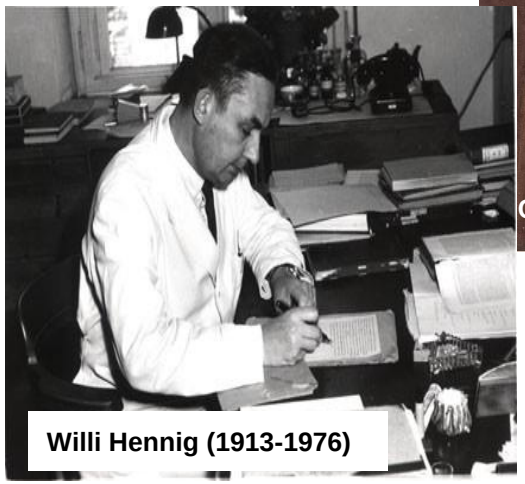
- **Linnésche Taxonomie**

  - **Universalität der binominalen Nomenklatur & Klassifikation**


Charles Darwin (1809-1882)

- **Darwin - Evolution & Genealogie**

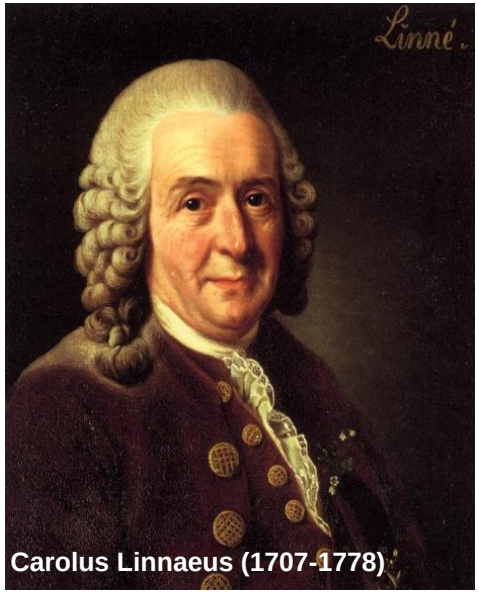
"The natural system [of classification] is founded on descent with modification, …and in so far, all true classification is genealogical" **(Darwin 1859)**


Willi Hennig (1913-1976)

- **Hennig – Prinzipien phylogenetischer Systematik**

Taxonomie und Biosystematik

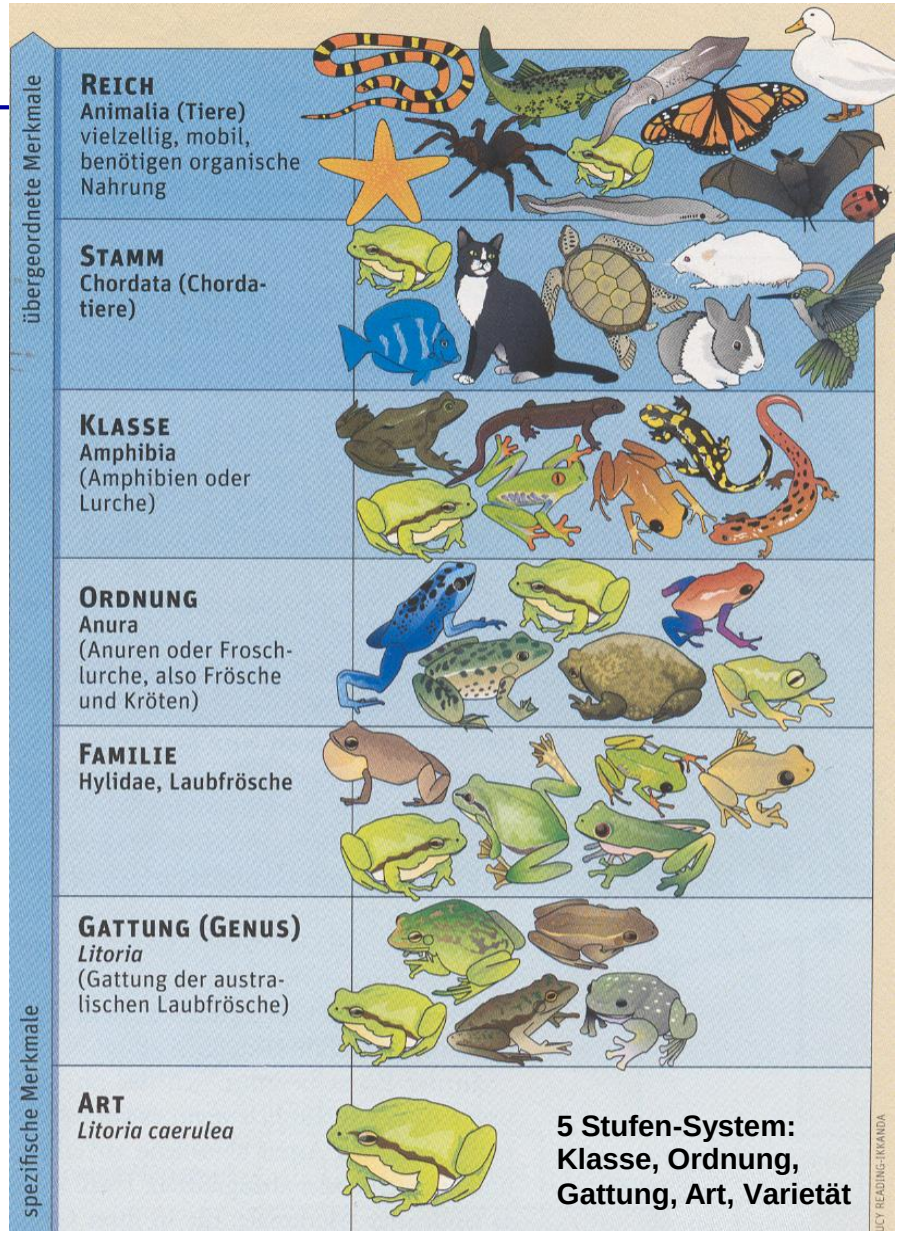
- **Linnésche Taxonomie**



Carolus Linnaeus (1707-1778)

Carl von Linné

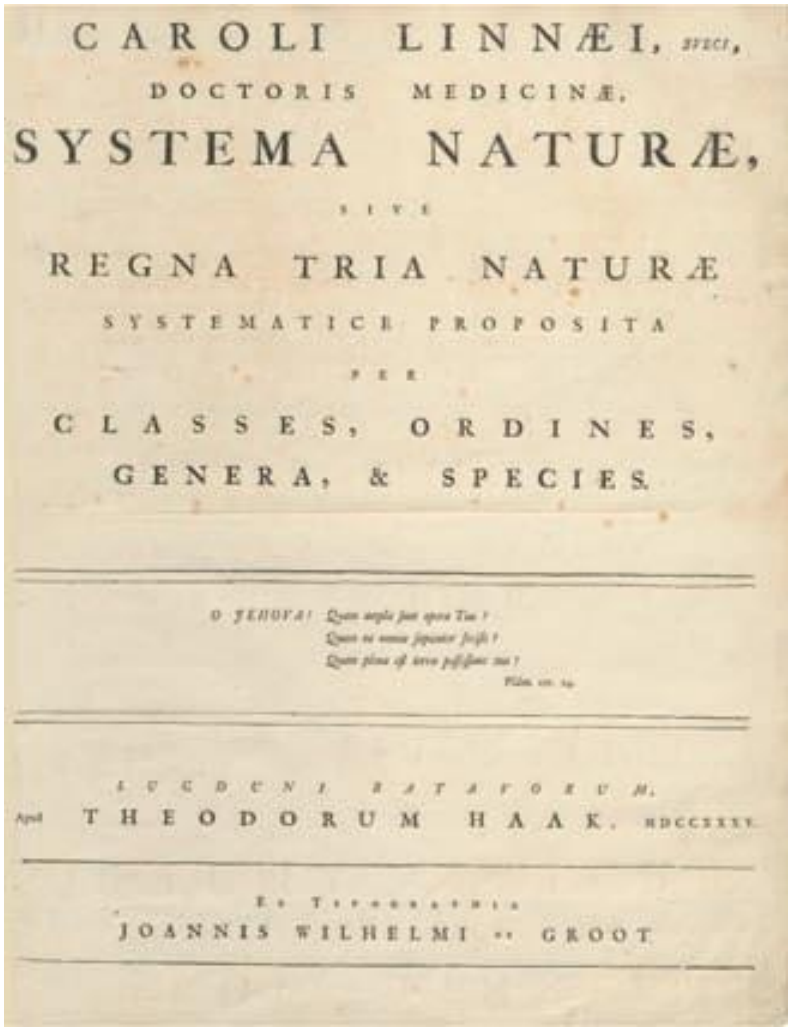
- **biologische Systematik begründet**
- **Entwurf eines enkaptischen Systems**
- **Einführung der binominalen Nomenklatur**



Carl von Linné - die Anfänge der Systematik

- **Linné als Same**

- ***Systema Naturae*, 1735**



CAROLI LINNÆI, SVECI,
DOCTORIS MEDICINÆ,
SYSTEMA NATURÆ,
SIVE
REGNA TRIA NATURÆ
SYSTEMATICE PROPOSITA
PER
CLASSES, ORDINES,
GENERA, & SPECIES.

O JEHOVA! Quam ampla sunt opera Tua!
Quam ea omnia sapienter fecisti!
Quam plena est terra possessione tua!
Psalm. civ. 24.

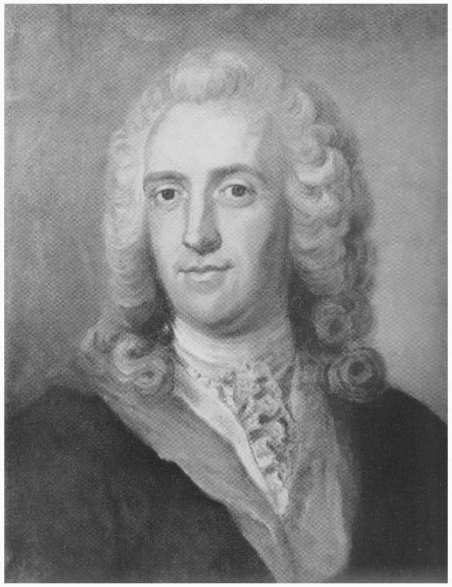
LUGDUNI BATAVORUM,
Apud THEODORUM HAAK. MDCCXXXV.

Ex Typographeio
JOANNIS WILHELMI ** GROOT

Der Meister aller Klassen – Zur Geschichte der Systematik

„Deus creavit, Linneaus disposuit“

“Gott hat die Welt erschaffen, Linné hat sie geordnet“



Carolus Linnaeus, 1753

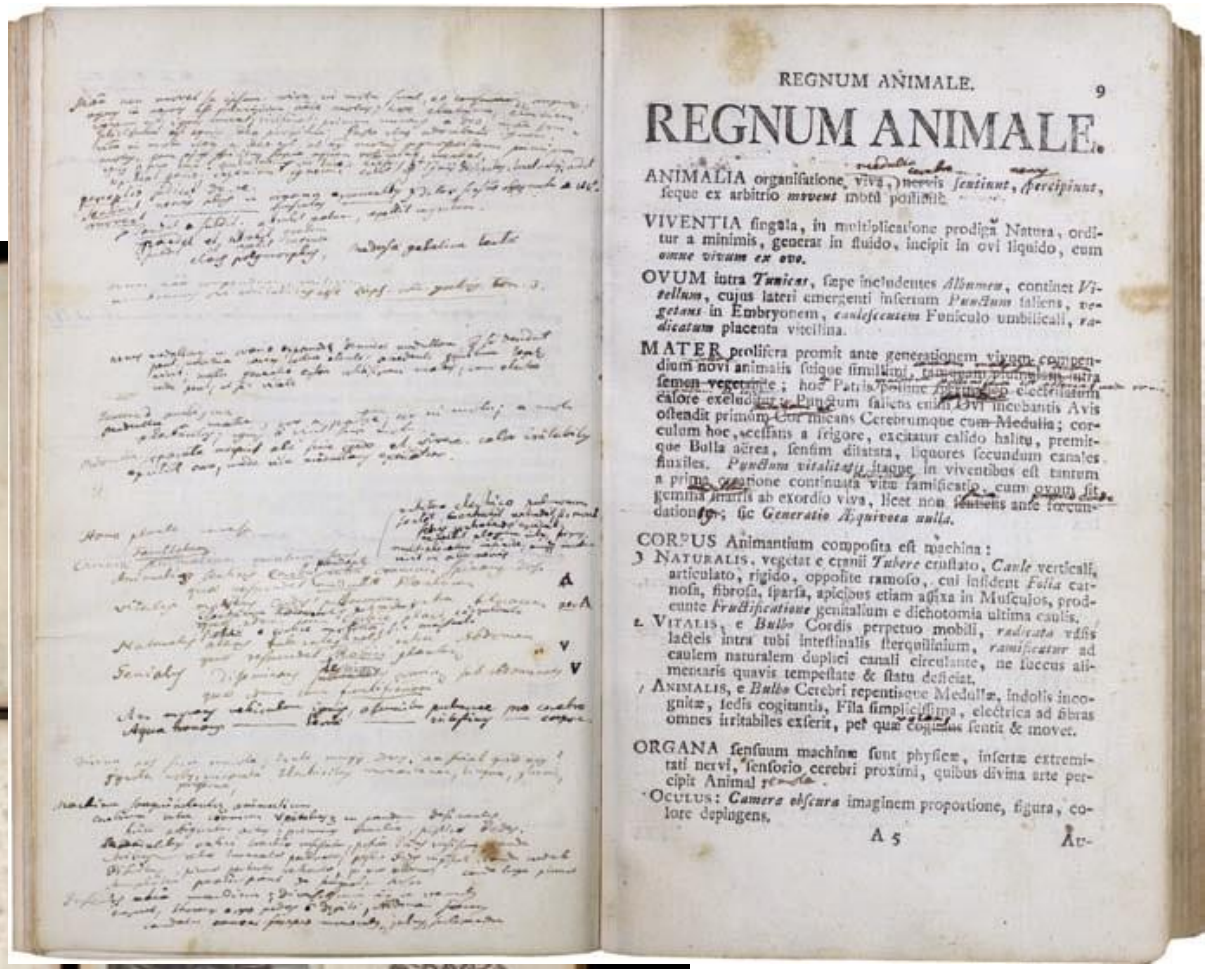
- **Beispiel Rote Johannisbeere:**
  - *Grossularia multiplici acino seu non spinosa hortensis rubra seu Ribes officinarium* - Caspar Bauhin (1560-1624)
  - *Ribes rubrum* - Linné 1753
- **Gattungen als natürliche Grundlage**
- **Konstanz der Arten**

Linné: *„Es gibt so viele Arten, wie das Unendliche Wesen zu Anbeginn erschaffen hat“*

Der Meister aller Klassen – Zur Geschichte der Systematik

- **Hauptwerke:**

1735 - *Systema Naturae*
(Leiden)

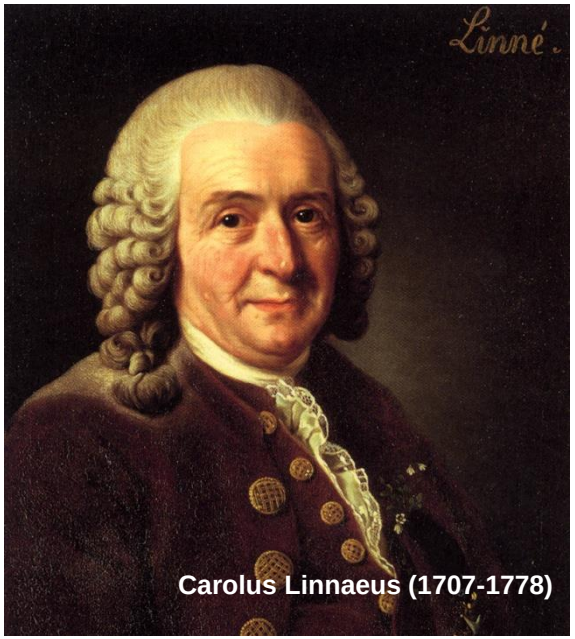


***Systema Naturae* 1758,**
von Linné mit zoologischen Beobachtungen ergänzt

Der Meister aller Klassen – Zur Geschichte der Systematik

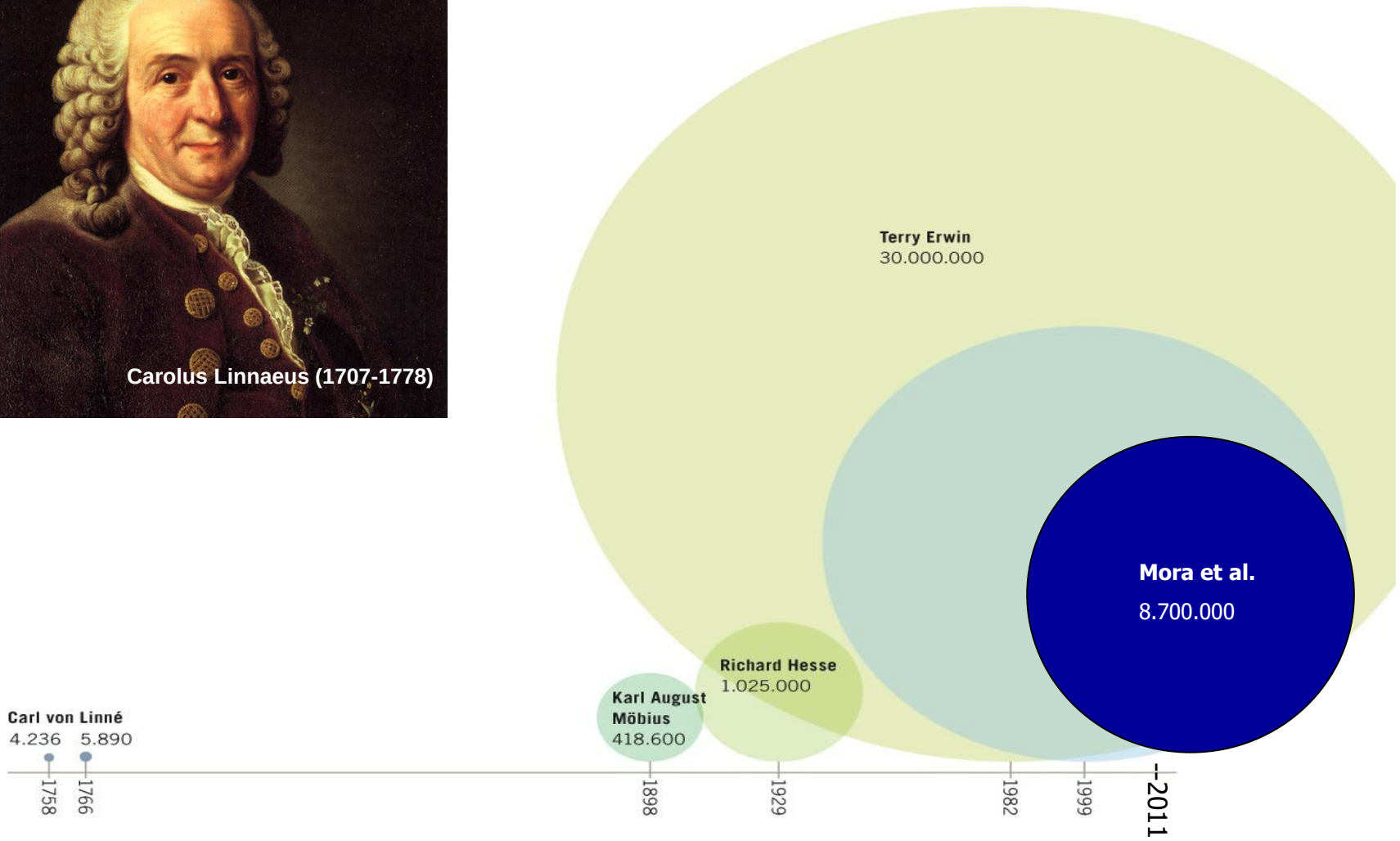
Reich	Animalia
Unterreich	Metazoa
	Bilateria
	Deuterostomia
Stamm	Chordata
Unterstamm	Vertebrata
Überklasse	Gnathostoma
Reihe	Tetrapoda
Klasse	Mammalia
Unterklasse	Eutheria
Ordnung	Primates
Unterordnung	Simiae
Überfamilie	Hominoidea
Familie	Hominidae
Gattung	*Homo*
Art	*Homo sapiens* Linnaeus, 1758

Das Linnésche Programm – Zoologie und Systematik

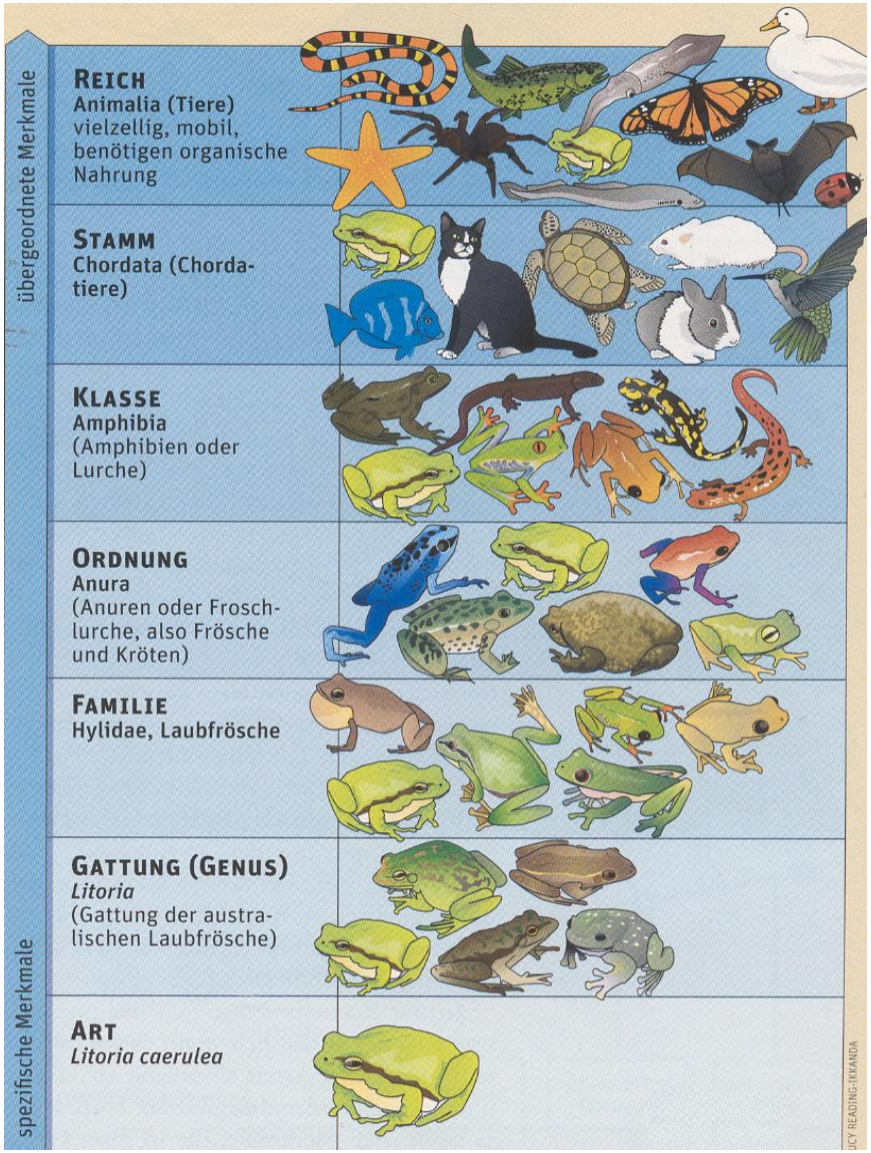


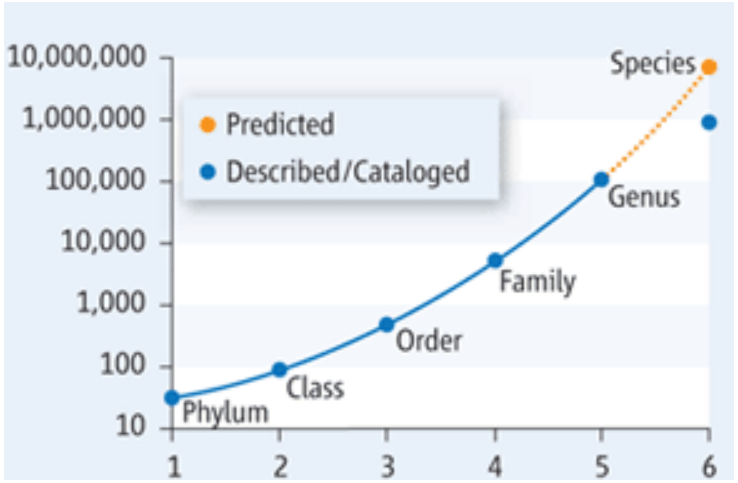
Carolus Linnaeus (1707-1778)

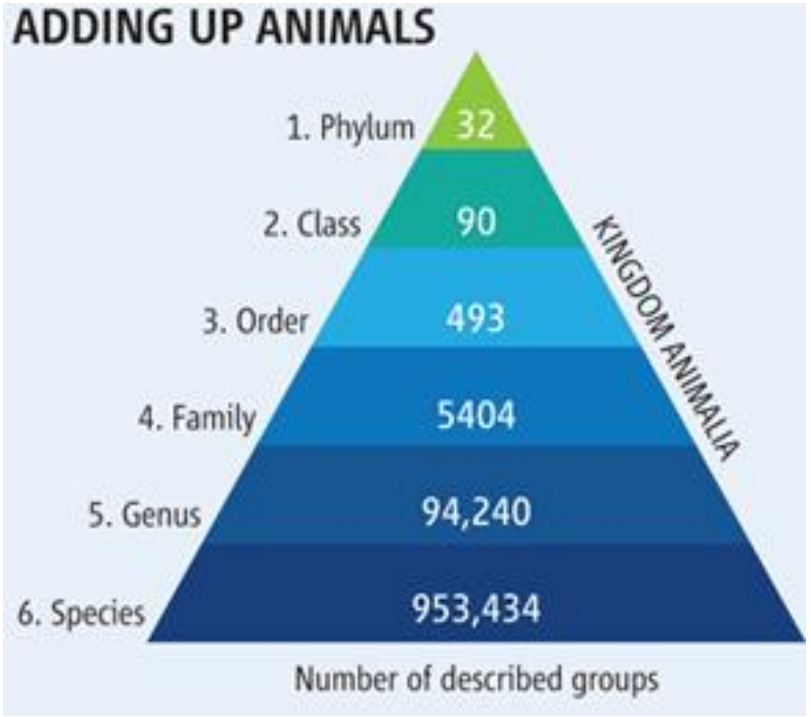
- **Wie viele Arten gibt es auf der Erde?**



Linnésche Klassifikation

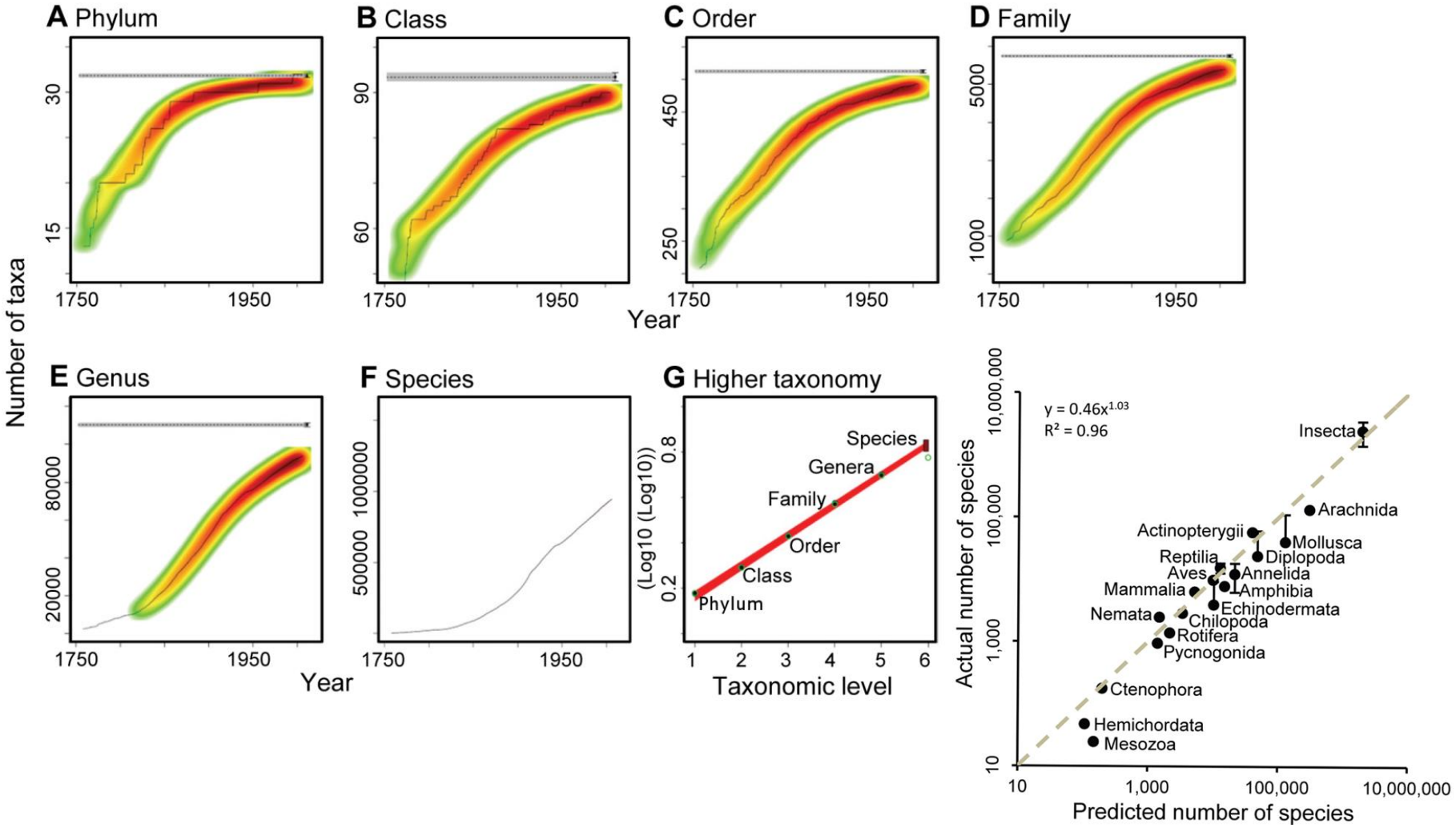






Strain, D. 2011. Science

Die Frage der Artenzahl

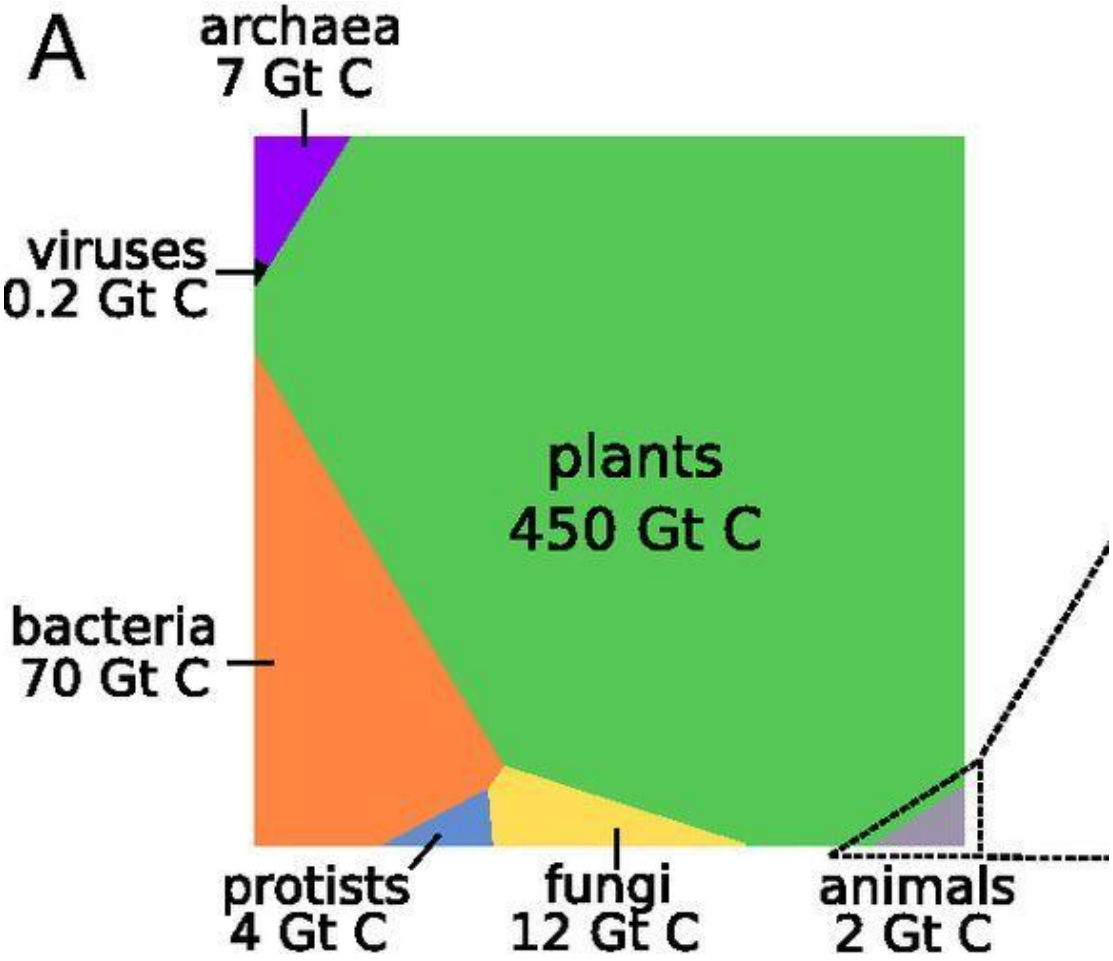


Mora et al. (2011) – PLoSOne

Biodiversität – Der Planet der Anderen

- **Wie verteilt sich das Leben auf der Erde ? – In Kohlstoffanteilen (Gt C)**

z.B. Mensch 70 kg = ~ 16 kg Kohlenstoff



Bar-On, Phillips & Ron Milo et al. (2018) - PNAS

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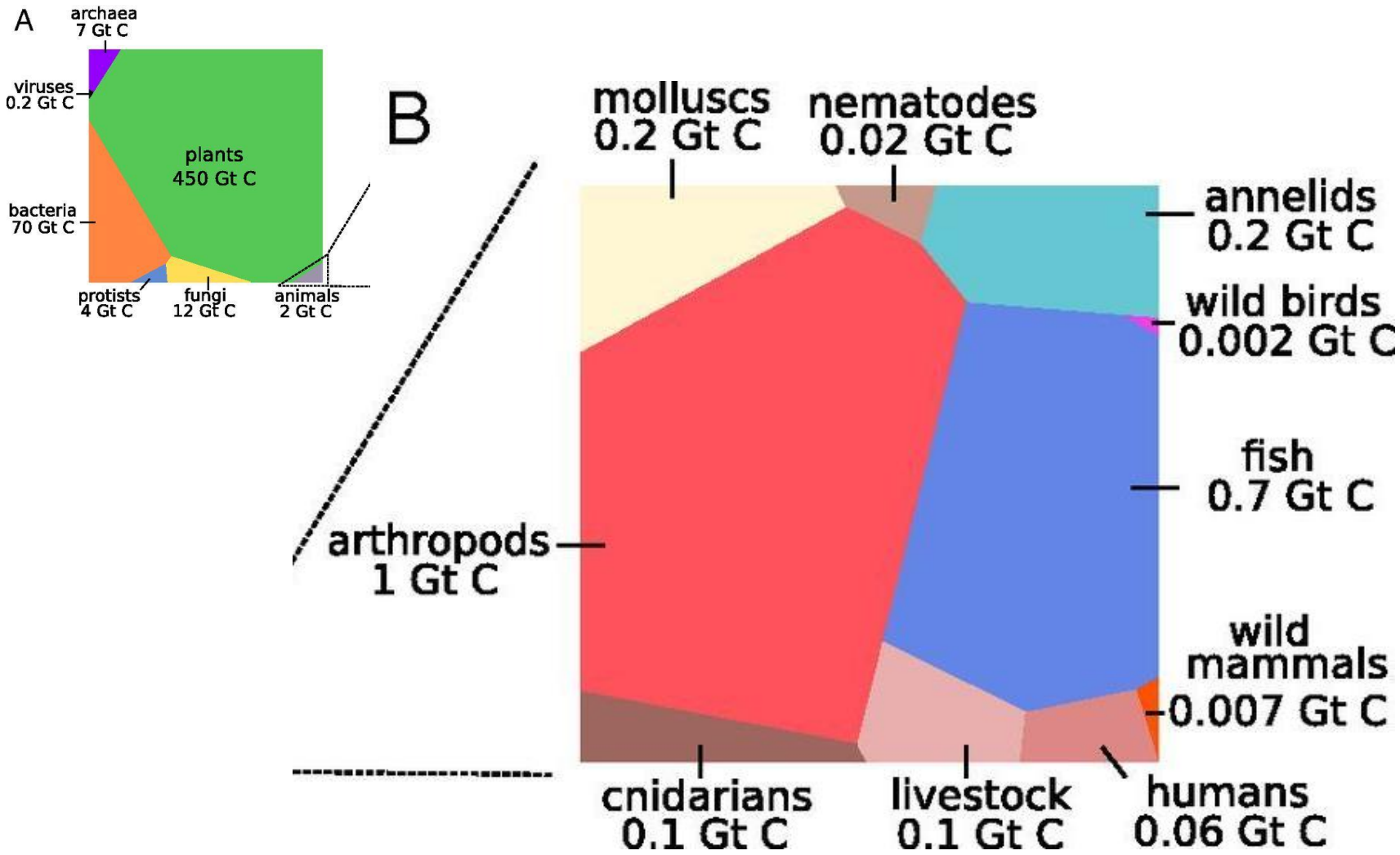
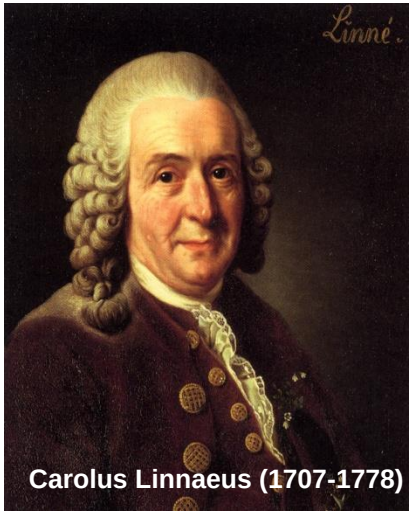


Bar-On, Phillips & Ron Milo et al. (2018) - PNAS

Taxonomie und Biosystematik

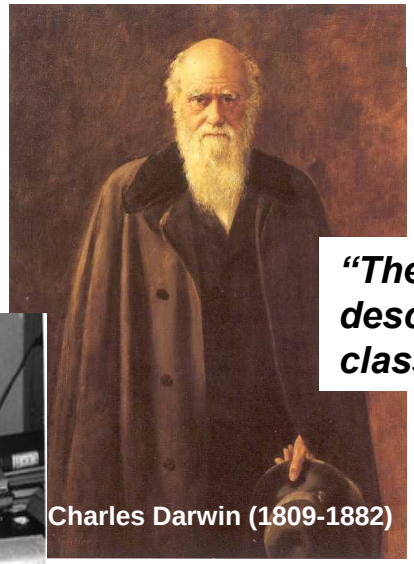
Von der ersten "*bioinformation crisis" zur* phylogenetischen Klassifikation



Carolus Linnaeus (1707-1778)

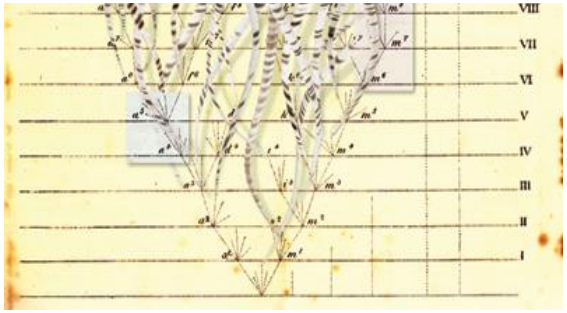
- **Linnésche Taxonomie**

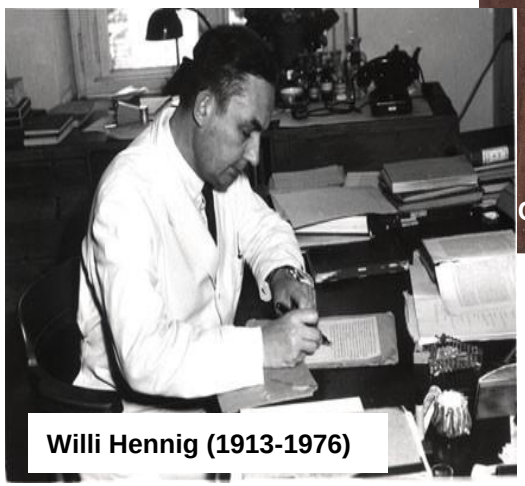
  - **Universalität der binominalen Nomenklatur & Klassifikation**


Charles Darwin (1809-1882)

- **Darwin - Evolution & Genealogie**

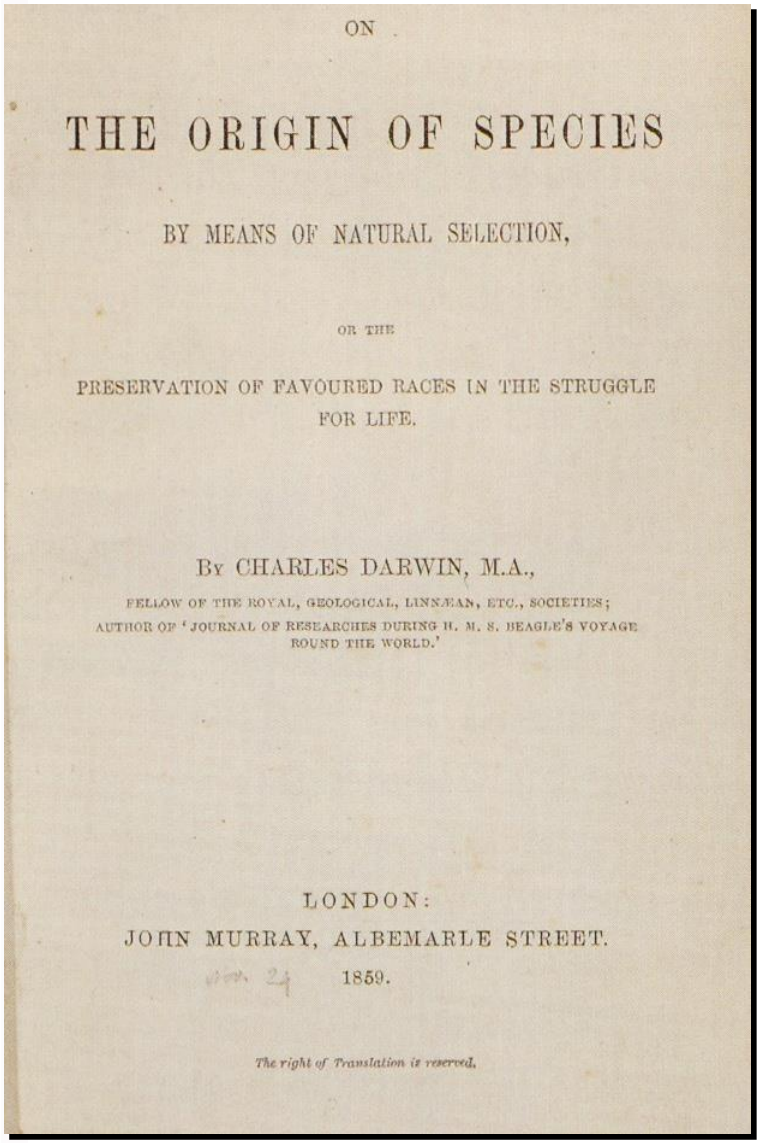
"The natural system [of classification] is founded on descent with modification, …and in so far, all true classification is genealogical" **(Darwin 1859)**




Willi Hennig (1913-1976)

- **Hennig – Prinzipien phylogenetischer Systematik**

Darwins „Origin of Species“ , 1859



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

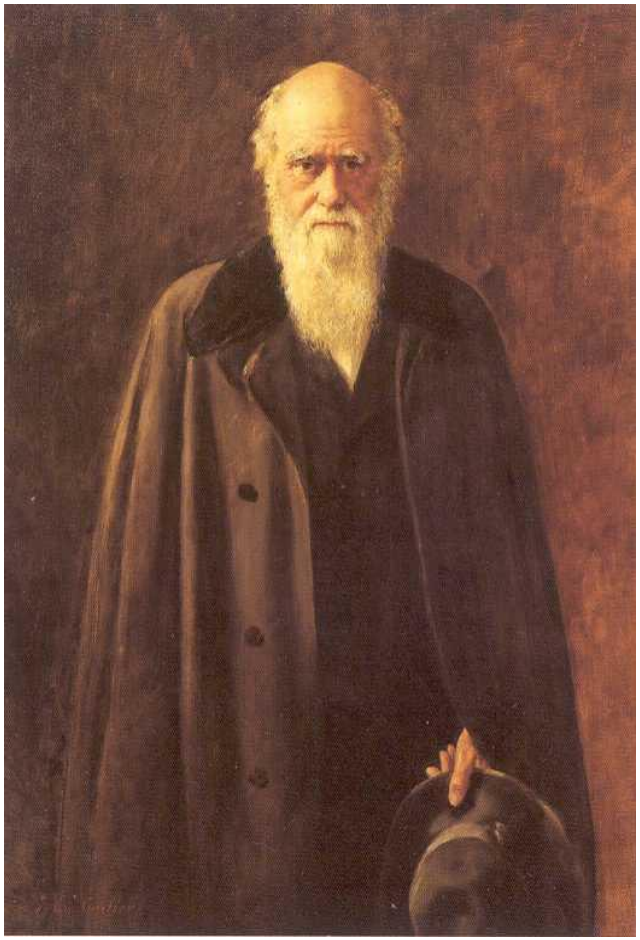
PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

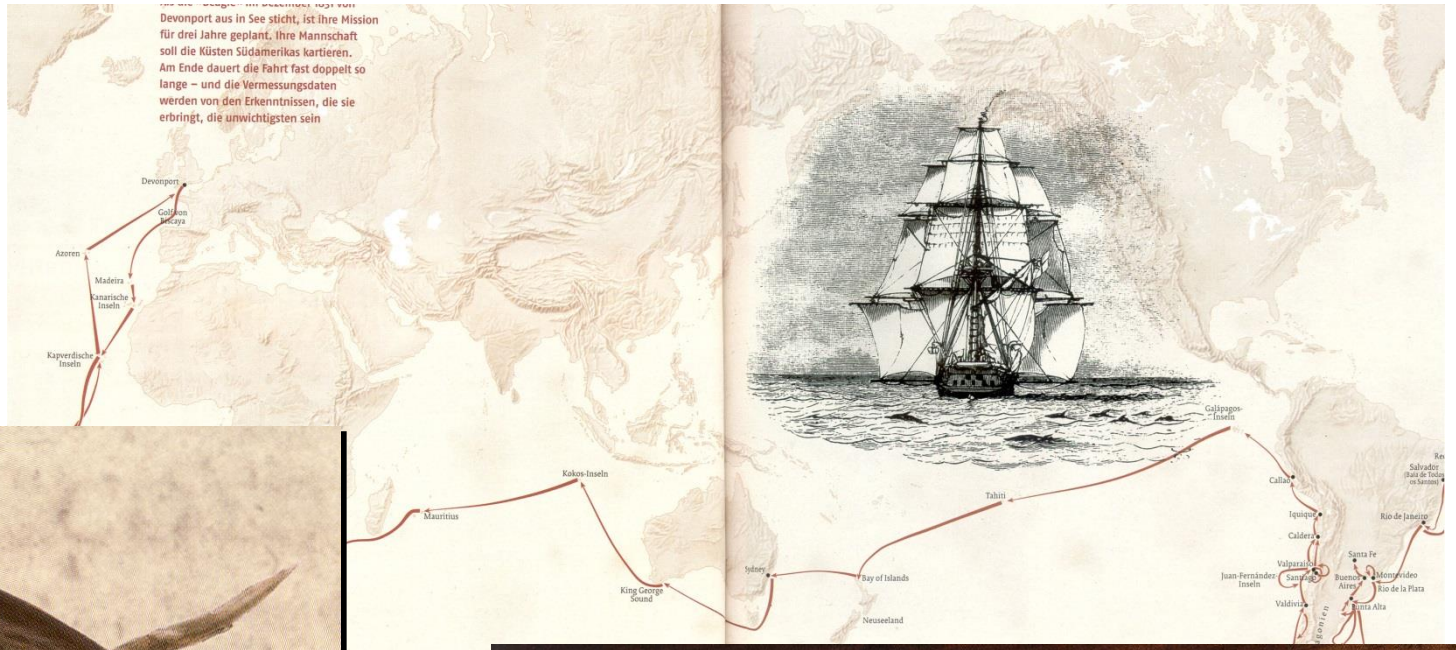
The right of Translation is reserved.

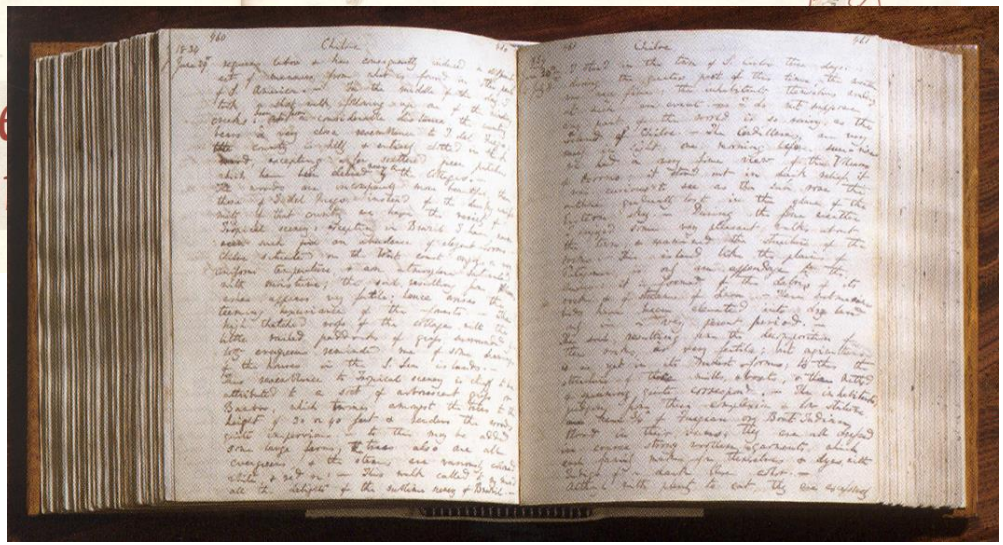


Charles Darwin (1809-1882)

Charles Darwin, an Bord „H.M.S. Beagle“, 1831 - 1836

- “… der Anstoss zu all meinen Überlegungen“

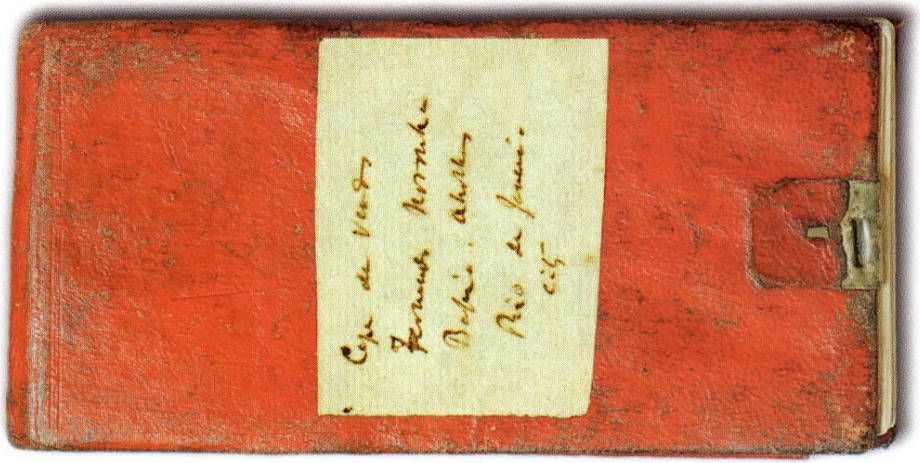


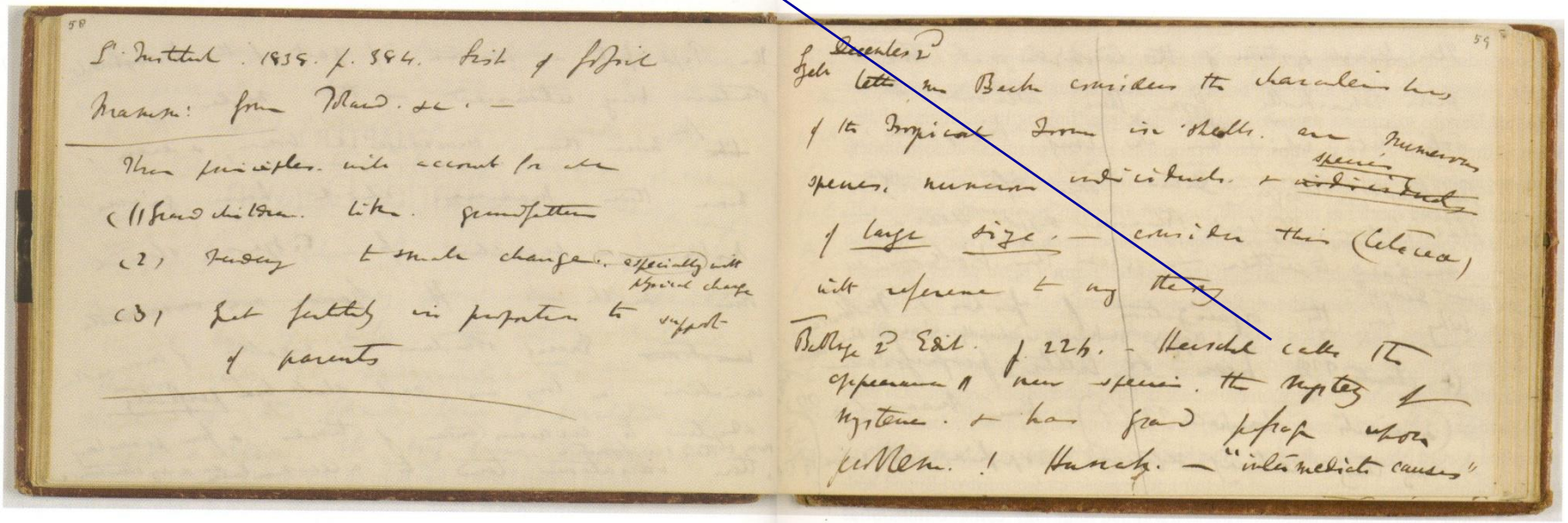


Charles Darwins Notizbücher

„*Red Notebook*“ – März 1837

„ … calls the appearance of new species the mystery of mysteries.“





Darwins „*Geheimnis der Geheimnisse*“

ON THE ORIGIN OF SPECIES.

INTRODUCTION.

When on board H.M.S. ‘Beagle,’ as naturalist, I was much struck with certain facts in the distribution of the inhabitants of South America, and in the geological relations of the present to the past inhabitants of that continent. These facts seemed to me to throw some light on the origin of species—that mystery of mysteries, as it has been called by one [illegible]. On my return home, it o[illegible] something might perhaps b[illegible] by patiently accumulating and reflecting on all sorts of facts which could possibly have any bearing on it. After five years’ work I allowed myself to speculate on the subject, and drew up some short notes; these I enlarged in 1844 into a sketch of the conclusions, which then seemed to me probable: from that period to the present day I have steadily pursued the same object. I hope that I may be excused for entering on these personal details, as I give them to show that I have not been hasty in coming to a decision.

My work is now nearly finished; but as it will take me two or three more years to complete it, and as my health is far from strong, I have been urged to publish this Abstract. I have more especially been induced to do this, as Mr. Wallace, who is now studying the

...- that mystery of mysteries, ...

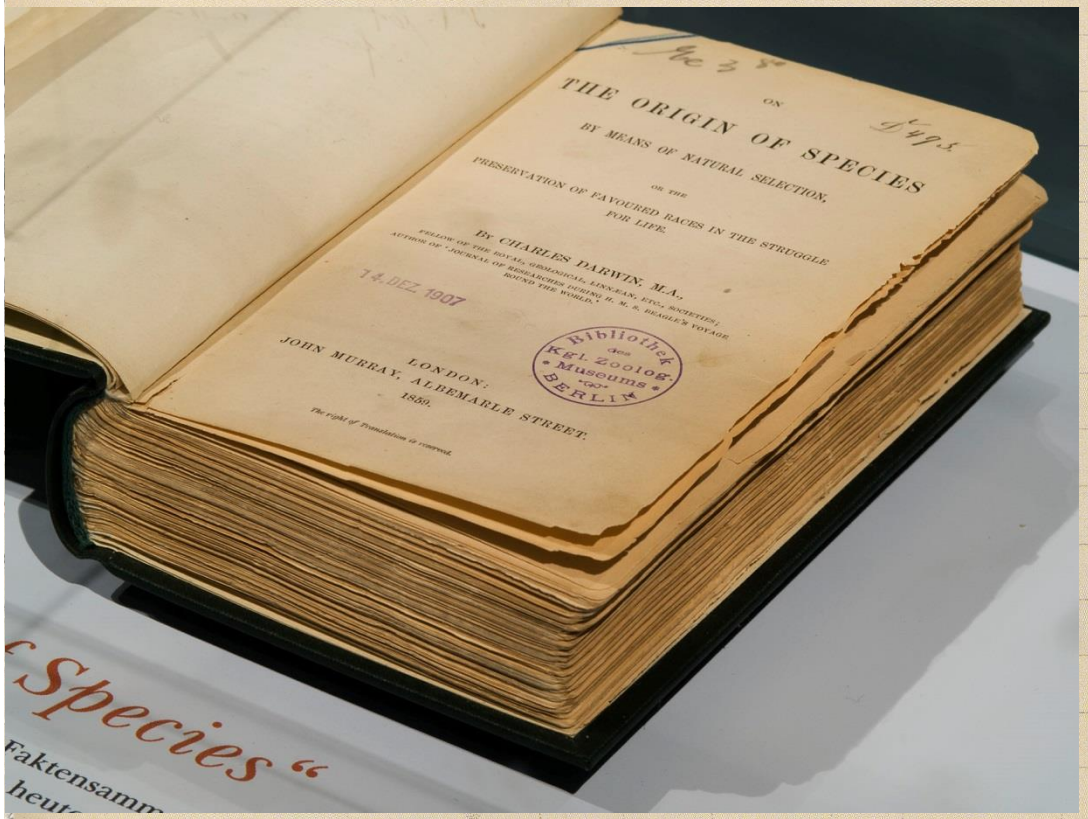
brief recapitulation of the whole work, and a few concluding remarks.

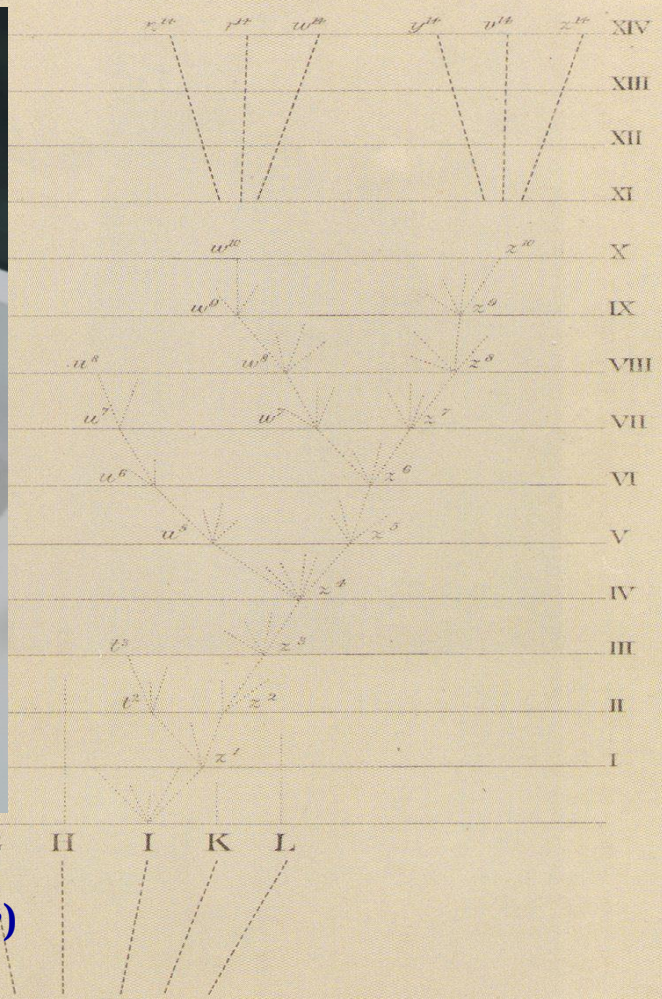
No one ought to feel surprise at much remaining as yet unexplained in regard to the origin of species and varieties, if he makes due allowance for our profound ignorance in regard to the mutual relations of all the beings which live around us. Who can explain why one species ranges widely and is very numerous, and why another allied species has a narrow range and is rare? Yet these relations are of the highest importance, for they determine the present welfare, and, as I believe, the future success and modification of every inhabitant of this world. Still less do we know of the mutual relations of the innumerable inhabitants of the world during the many past geological epochs in its history. Although much remains obscure, and will long remain obscure, I can entertain no doubt, after the most deliberate study and dispassionate judgment of which I am capable, that the view which most naturalists entertain, and which I formerly entertained—namely, that each species has been independently created—is erroneous. I am fully convinced that species are not immutable; but that those belonging to what are called the same genera are lineal descendants of some other and generally extinct species, in the same manner as the acknowledged varieties of any one species are the descendants of that species. Furthermore, I am convinced that Natural Selection has been the main but not exclusive means of modification.

...that Natural Selection has been the main ...means of modification

Darwins „mystery of mysteries"

- **Wie entstehen neue Arten?**

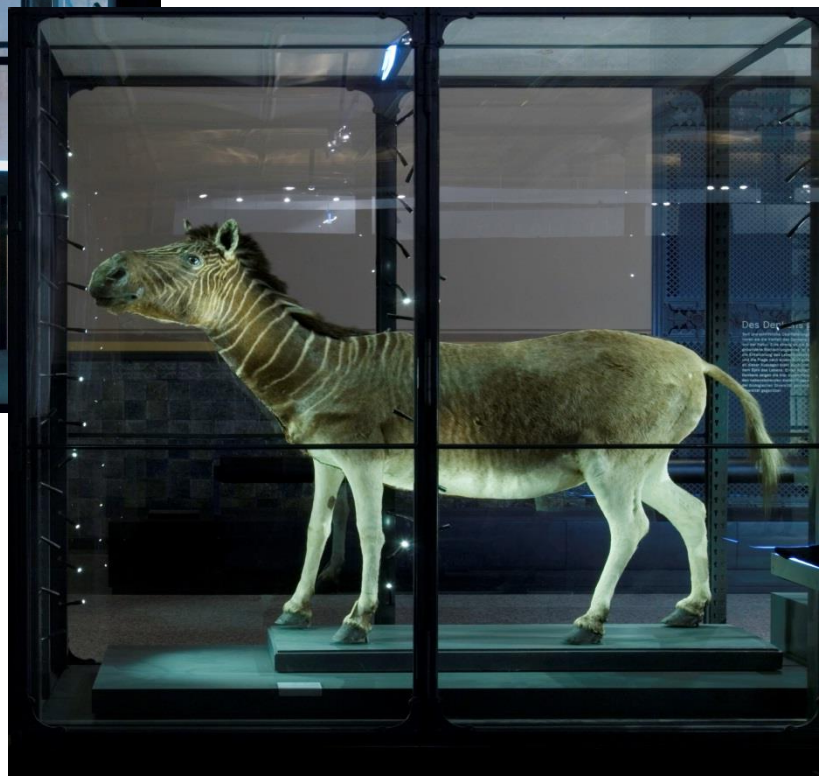




- **Evolution durch „*natural selection*" - (*Anagenese*)**
- **Multiplikation der Arten - (*Kladogenese*)**

Darwins originäre Idee: Natürliche Selektion

Warum das Zebra Streifen hat …



… und das Quagga sie wieder verlor

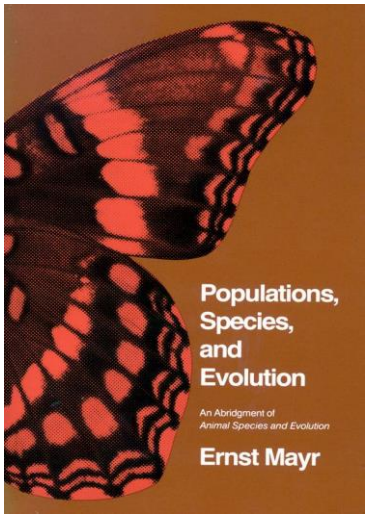
Meilensteine der Zoosystematik

Entwicklung neuer und Überarbeitung bestehender Konzepte

- **Konzept der biologischen Art:**

„Berliner Schule“ - Stresemann, Rensch, Mayr

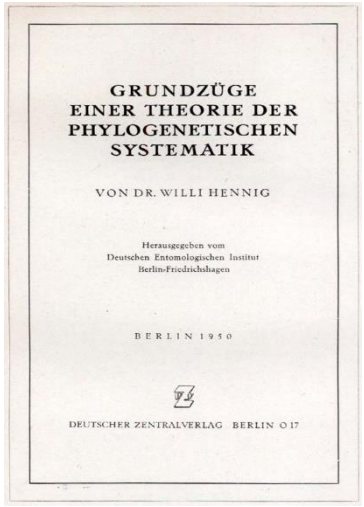
„*population thinking*“ (E. Mayr 1959, 1982)



- **Konzept des phylogenetischen Systems:**

Kladistik - Willi Hennig

„*tree thinking*“ (R. O‘Hara 1988)


GRUNDZÜGE
EINER THEORIE DER
PHYLOGENETISCHEN
SYSTEMATIK

VON DR. WILLI HENNIG

Herausgegeben vom
Deutschen Entomologischen Institut
Berlin-Friedrichshagen

BERLIN 1950

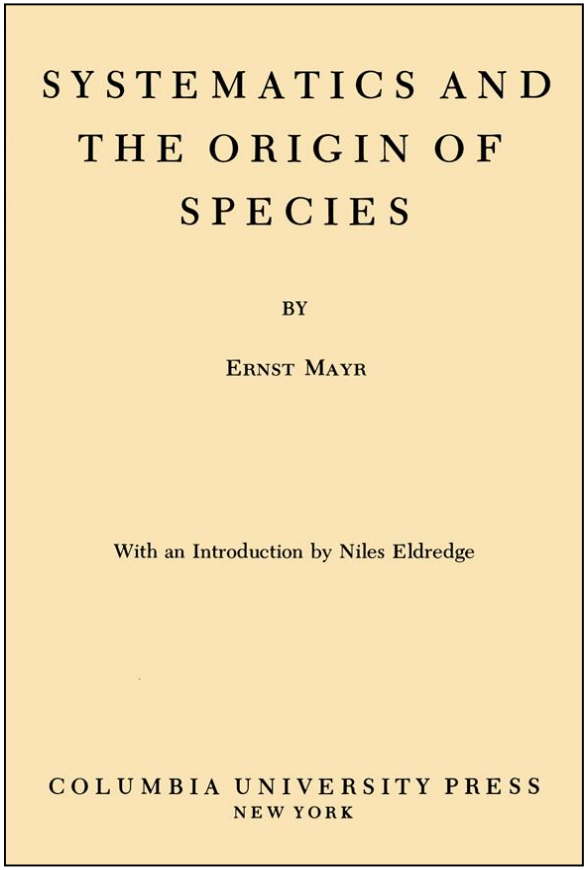
DEUTSCHER ZENTRALVERLAG BERLIN O 17

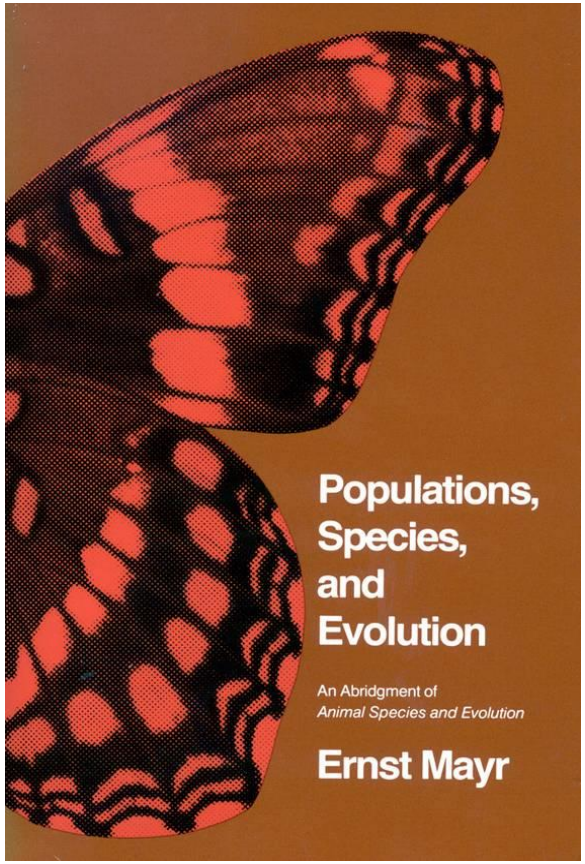
Architekt der modernen Evolutionstheorie – Ernst Mayr

- **Wie entstehen neue Arten ?**

  Speziation durch geographische Separation

Ernst Mayr (1904 - 2005)

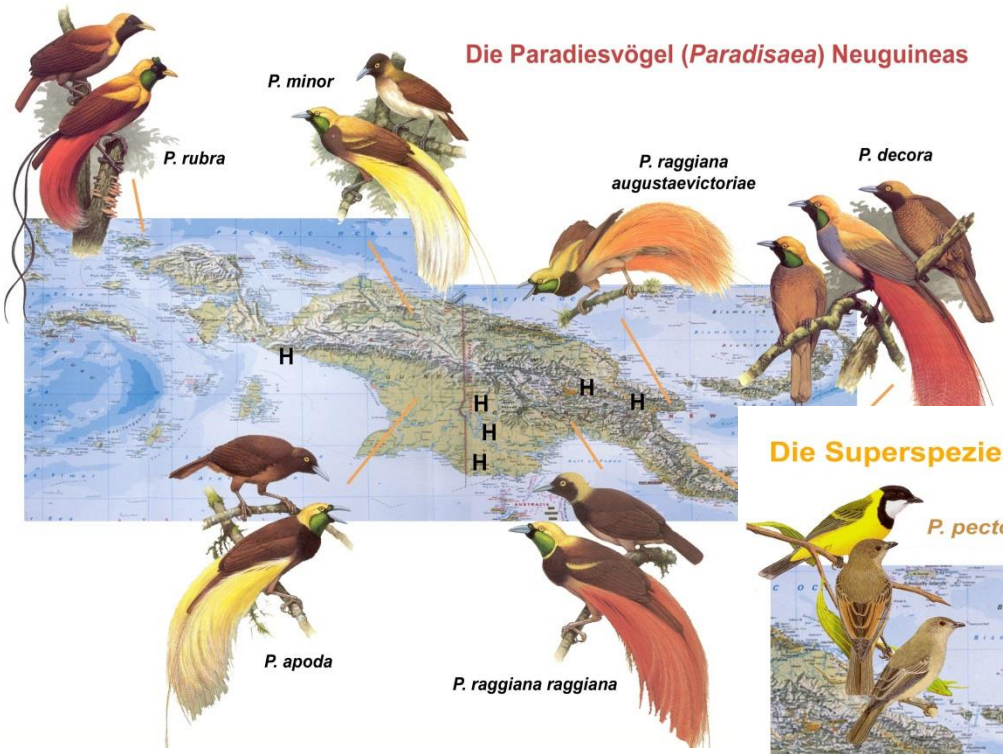




E. Mayr, 1942 / 1963

Ernst Mayr – Wie Arten entstehen

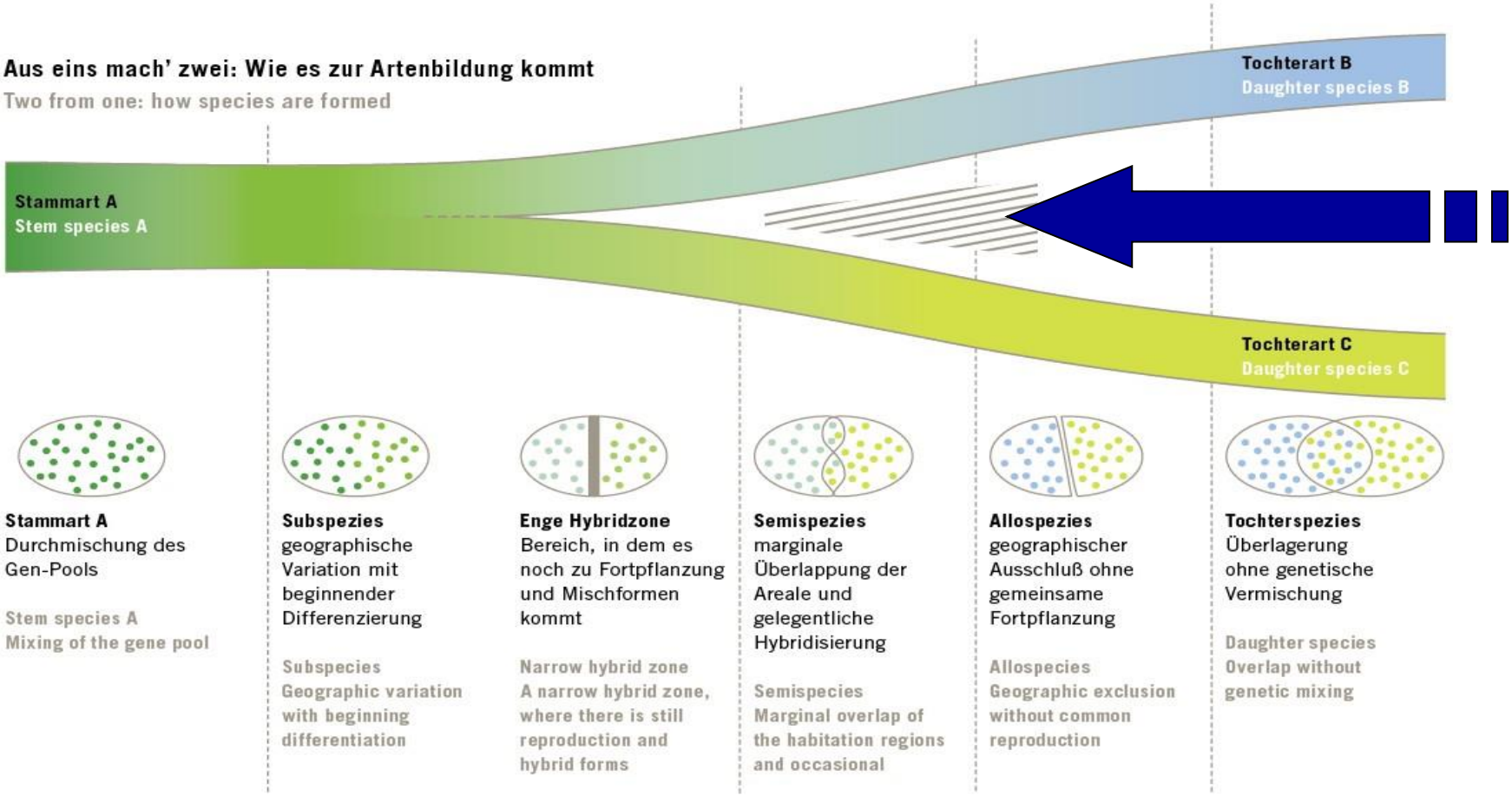
- **Die Avifauna des Südpazifiks: geographische Variation und Speziation**



- **Biospezies-Konzept**
- **allopatrische Speziation**

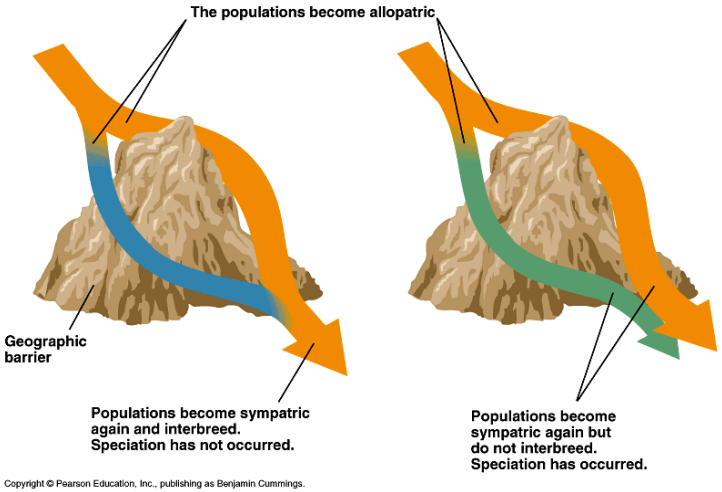
Die Hypothese allopatrischer Artenbildung

… als Ursache für die Biodiversität

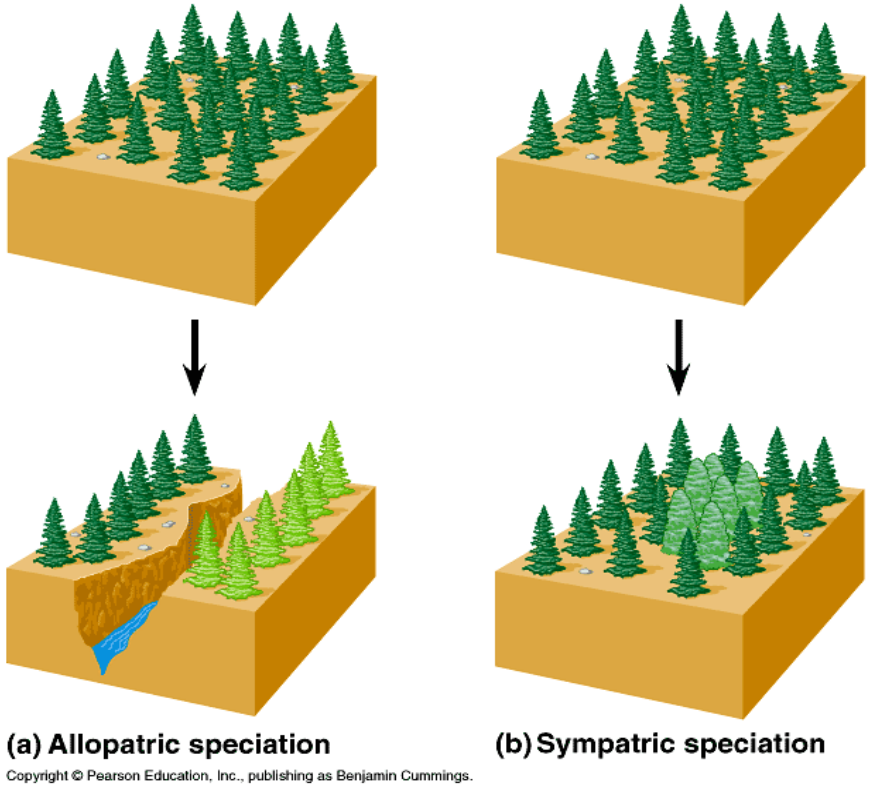


Mayrs Credo – Geographie und räumliche Trennung sind der Schlüssel

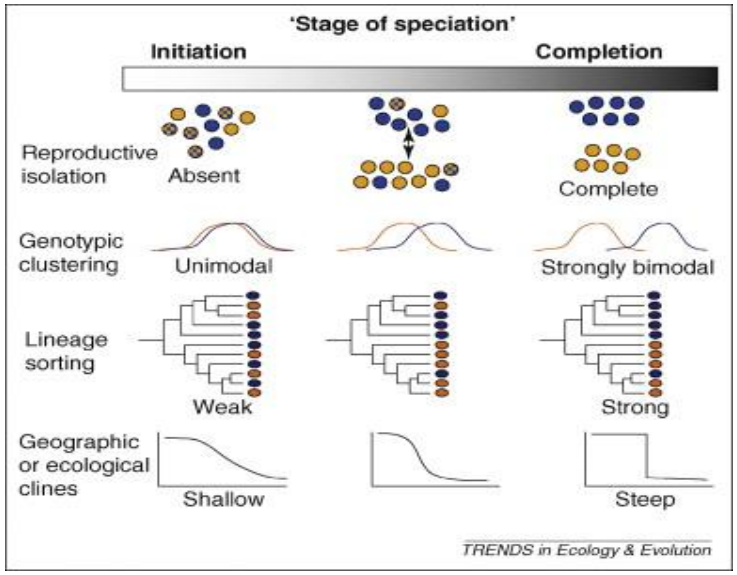
Wie entstehen neue Arten wirklich ?



Zwei geographische Modelle



Molekulare Phylogenien



Allopatrische Speziation = Standard-Hypothese

Ökologische Speziation

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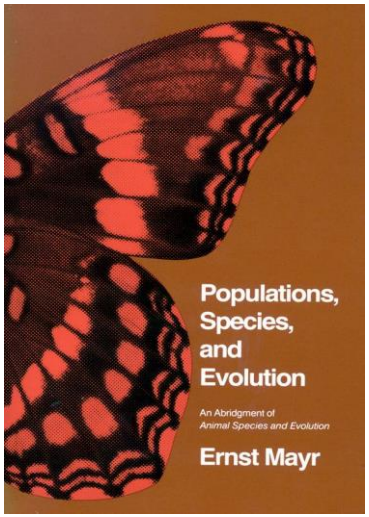

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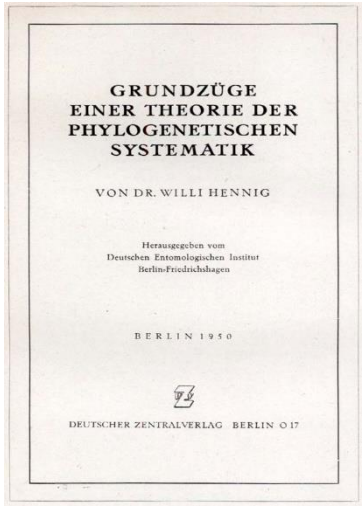
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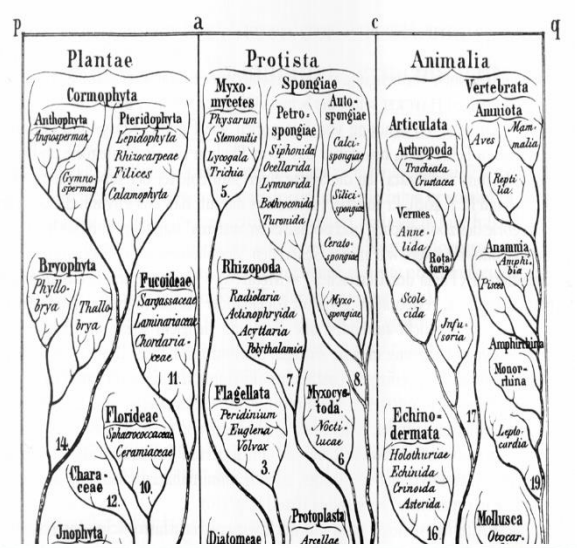
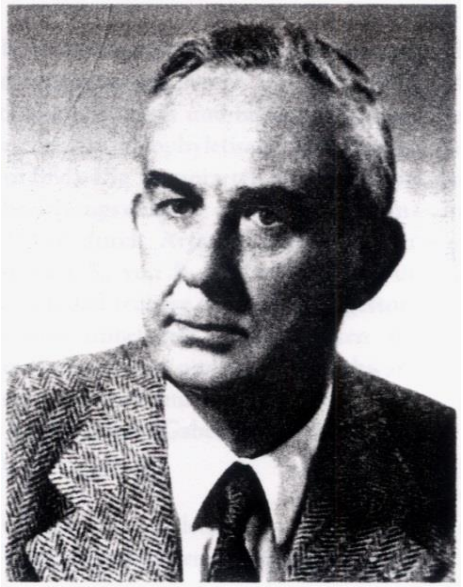
Architekt einer phylogenetischen Systematik – Willi Hennig



Transformation phylogenetischer Forschung

Willi Hennig (1913-1976)



- wichtigster Systematiker
- Begründer Phylogen. Systematik
- Hauptwerk „Gründzüge...“ (1950)

- unprätentiöser Museums-Entomologe

Taxonom / Diptera & Coleoptera

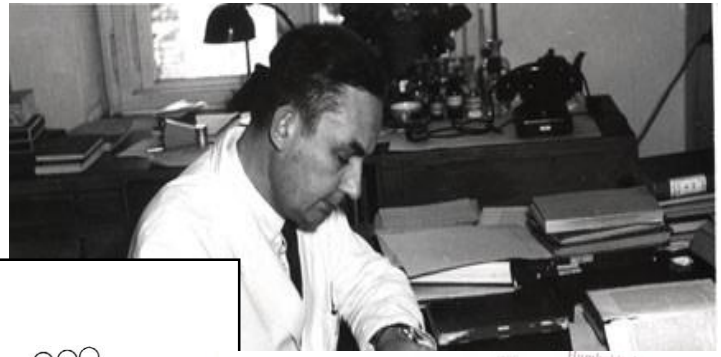
wiss. Assistent & Abtl.leiter DEI, 1937-1961

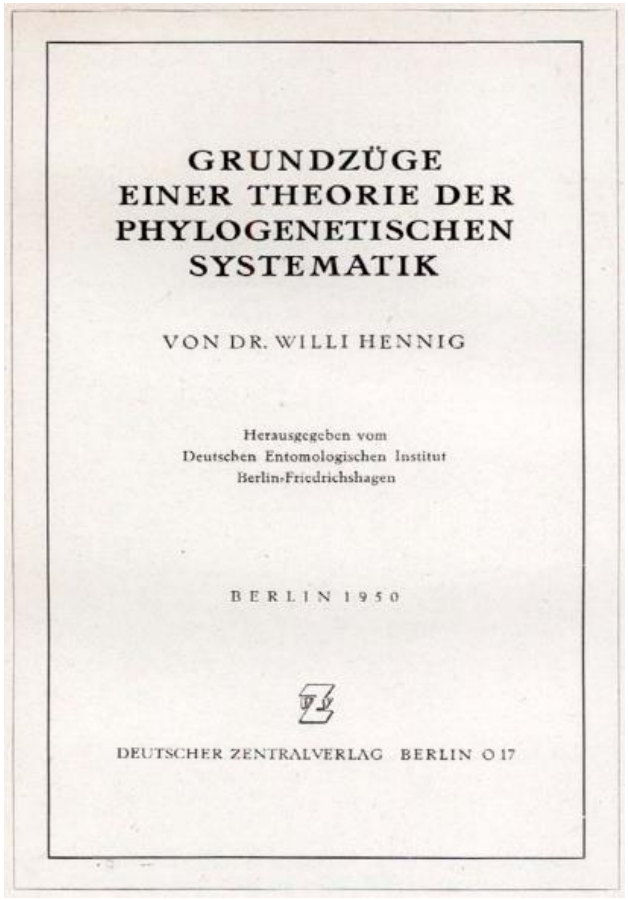
Staatl. Mus. Stuttgart (Ludwigsburg) ab 1963

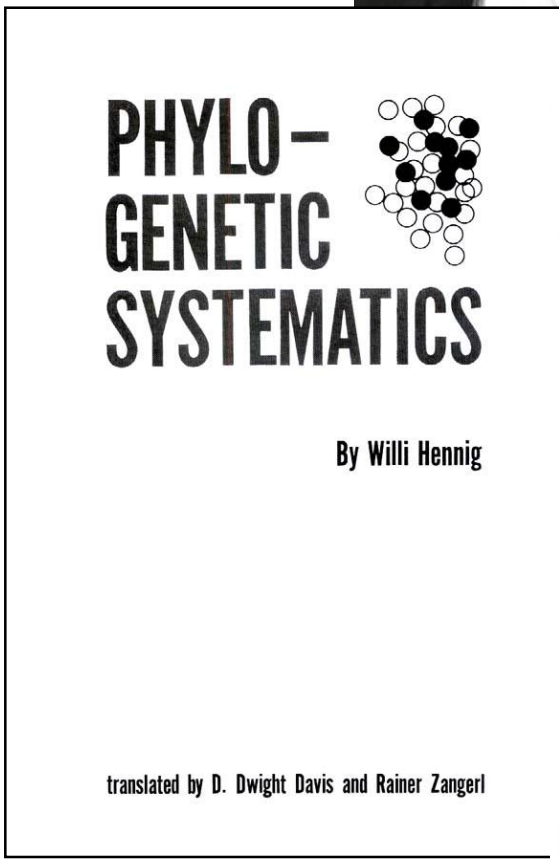
Architekt einer phylogenetischen Systematik – Willi Hennig

- **Wie läßt sich Verwandtschaft begründen ?**

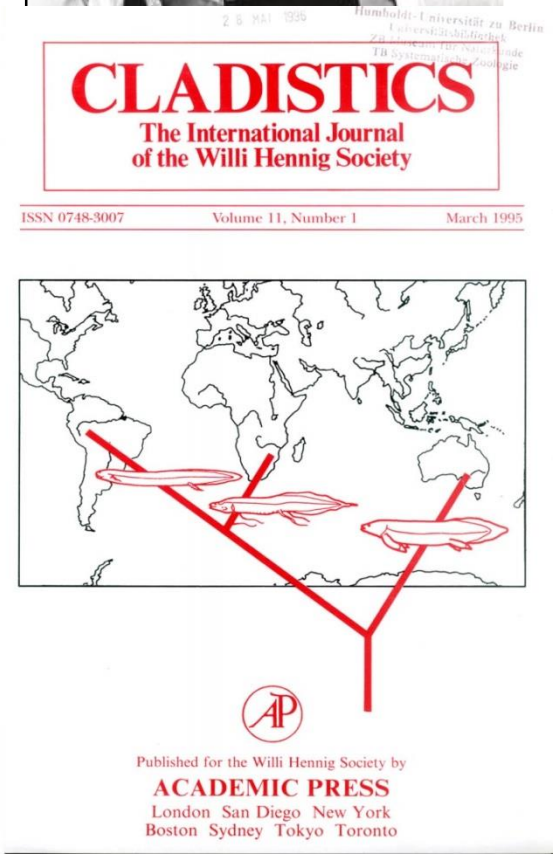
  Prinzipien der Phylogenie & Kladistik



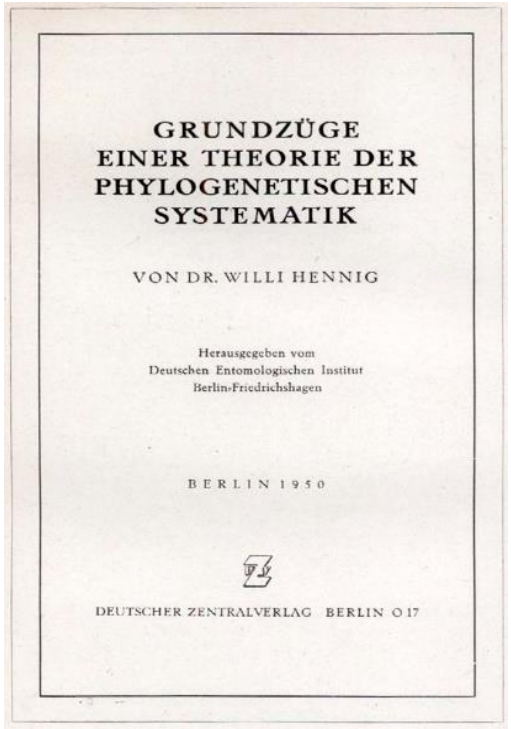




W. Hennig, 1950



Vom Merkmal zum Baum – Phylogenetische Systematik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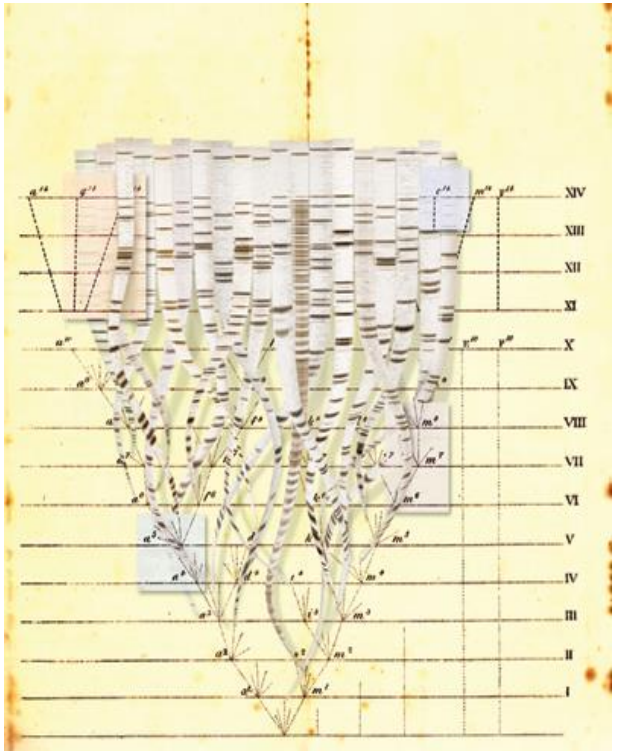
- **legt Unzulänglichkeit konventioneller systematischer Arbeit dar**

- **beschreibt methodisches Vorgehen zur Rekonstruktion der Phylogenie**

- empirisches Instrumentarium

- konsequenter & klarer Begriffsapparat

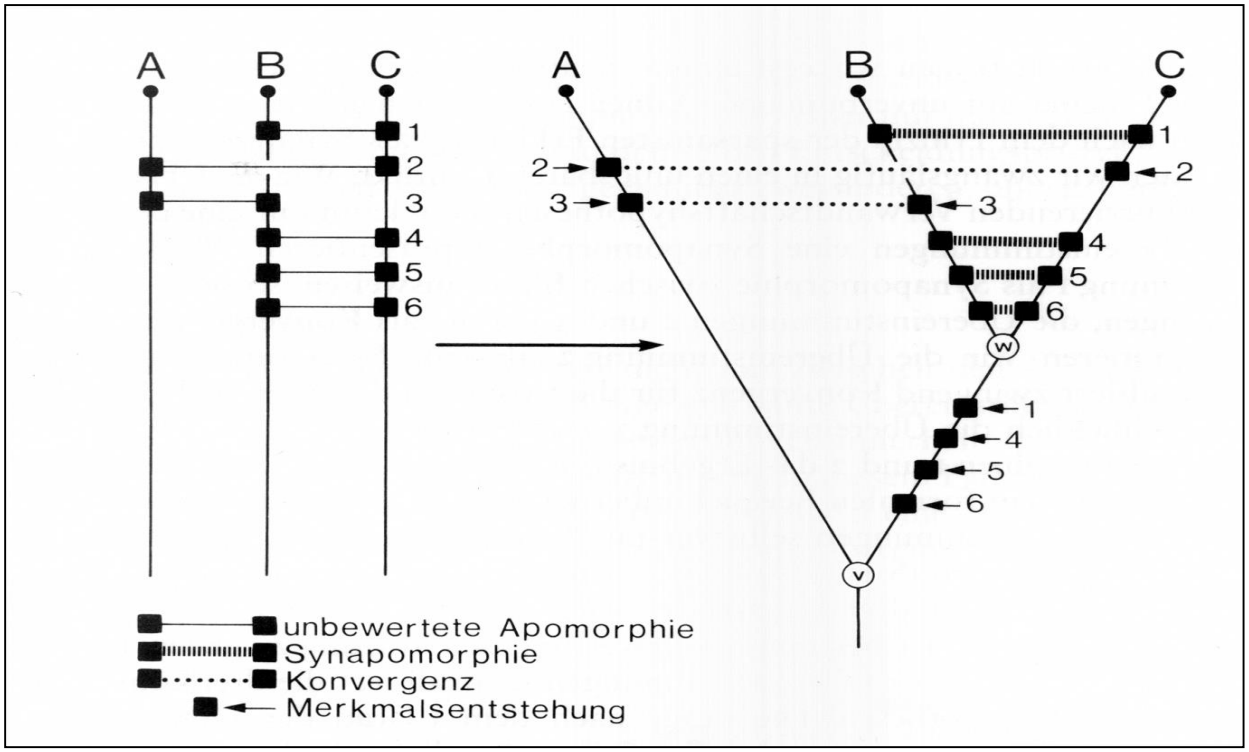


- **Grundlage: Darwins Evolutionstheorie**
  „common ancestry“

- *principium divisionis*: genealogisches Prinzip

Vom Merkmal zum Baum – Phylogenetische Systematik

- **stellt dar, wie man einwandfrei Verwandtschaft bestimmt**
- **klärt die Bedeutung von Homologie und Monophylie (rationales System)**
- **nutzt das Prinzip der sparsamsten Erklärung - „Ockham‘s razor“**



„*Ockham's razor*“ – Das Prinzip der sparsamsten Erklärung

Wilhelm von Ockham / William of Occam – ca. 1285-1349

- **aus Ockham bei London**
- **Franziskanermönch, Theologe & Philosoph, studierte in Oxford**
- **lehrte seit 1317 in Paris**
- **verhalf dem Nominalismus zum Durchbruch**
  (gegen den Begriffsrealismus des Thomas von Aquin)
- **wurde 1324 von der kathol. Kirche der Irrlehre beschuldigt, am päpstlichen Hof in Avignon in Untersuchungshaft gehalten**
- **floh 1328 über Pisa nach München zu Ludwig IV von Bayern, den er im Kampf gegen die Papstherrschaft unterstützt hatte**
- **starb 1349 in München**

„*Ockham's razor*“ – Das Prinzip der sparsamsten Erklärung

- **Parsimonieprinzip – Prinzip der Denkökonomie**

eine Regel, ein methodisches Hilfsmittel, zum Vergleich von Hypothesen

vermeidet unnötige *ad hoc* - Annahmen

Frage: Welche Annahmen reichen aus, um eine Erscheinung zu erklären?

- ***„Pluralitas non est ponenda sine necessitate“***

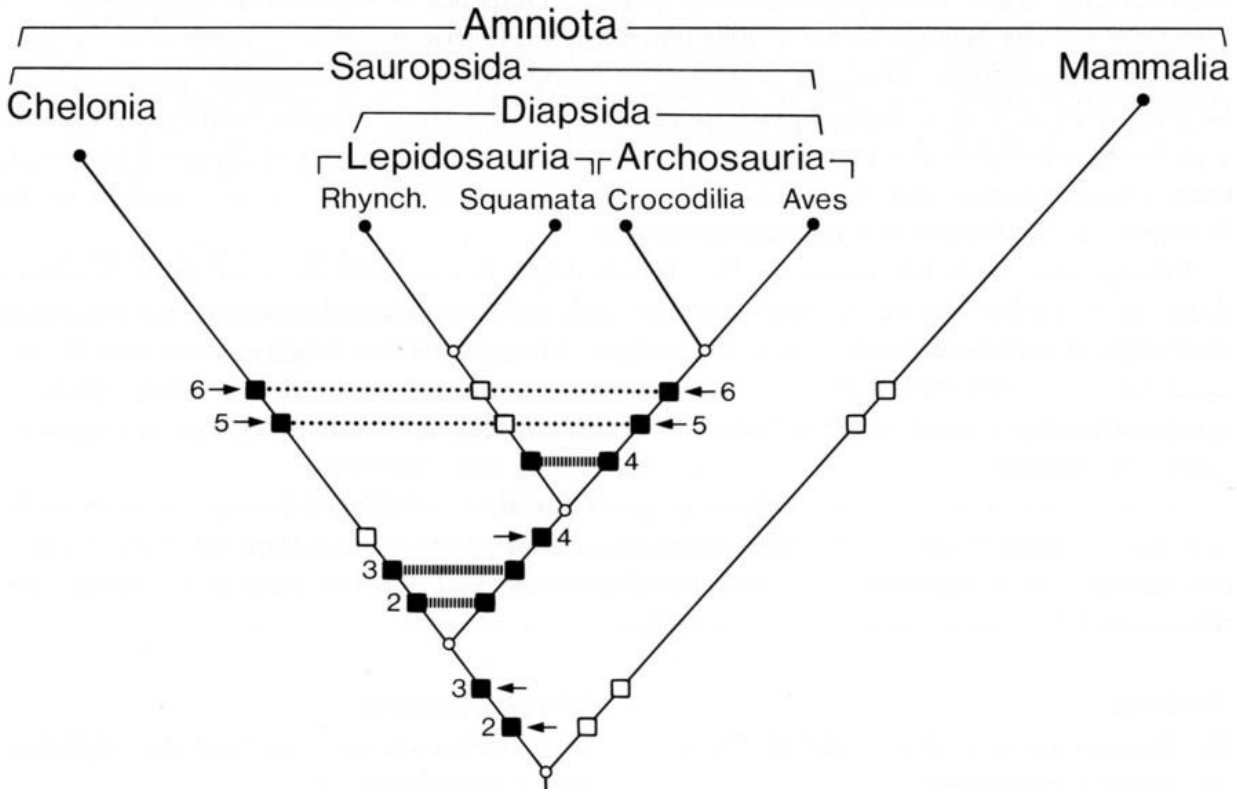
Ohne Notwendigkeit ist keine Vielfalt zu postulieren

Systematik:

- **phylogenetische Aussagen sind hypothetisch (*hypothetico-deductiv*)**
- **methodologisches Hilfsmittel zur Beurteilung von Hypothesen**

Einführung in die phylogenetische Systematik

- *„Der Tod der ‚Reptilien‘*



- **Hauptleistung:**

  Vereinigung zweier zuvor unabhängig betriebener Disziplinen

Taxonomie & Systematik

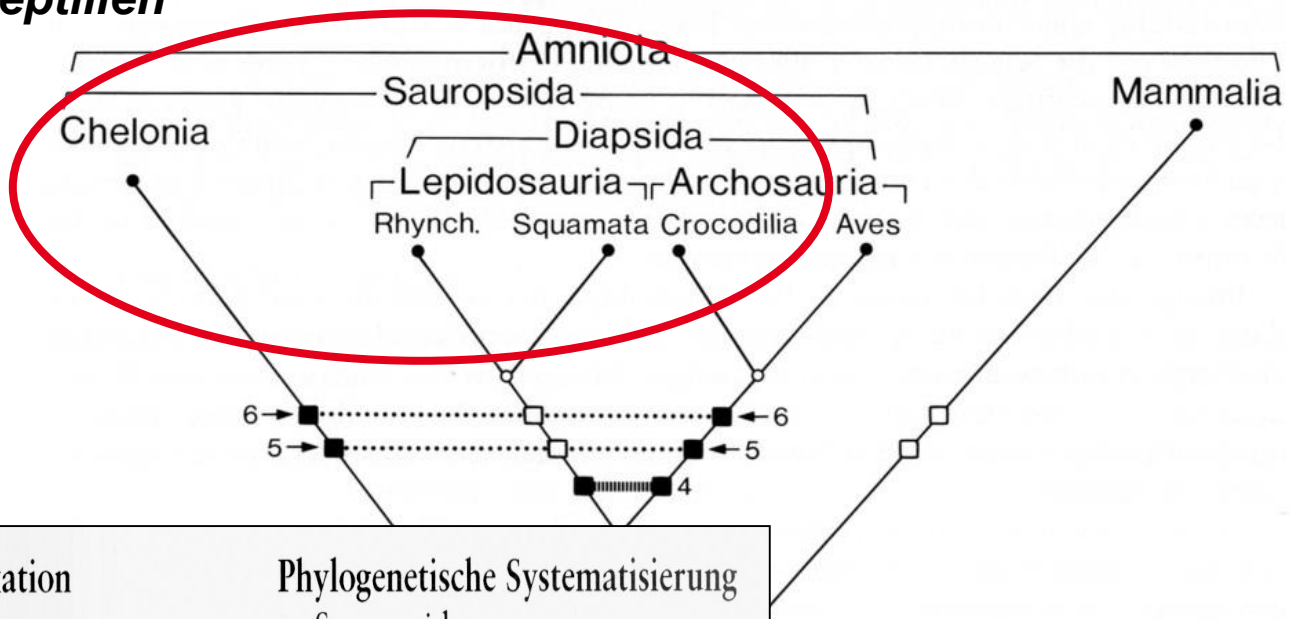
- beschreibt Artenvielfalt

Phylogenetik

- begründet Verwandtschaftshypothesen

Einführung in die phylogenetische Systematik

- ***„Der Tod der ‚Reptilien'***



Herkömmliche Klassifikation

1. Reptilia
   - 1.1. Chelonia
   - 1.2. Rhynchocephalia
   - 1.3. Squamata
   - 1.4. Crocodilia
2. Aves
3. Mammalia

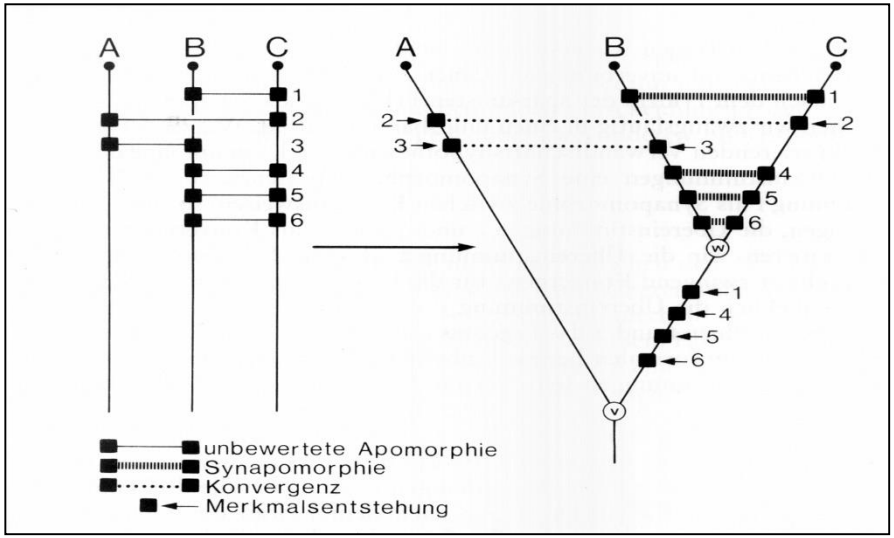
Paraphylie !

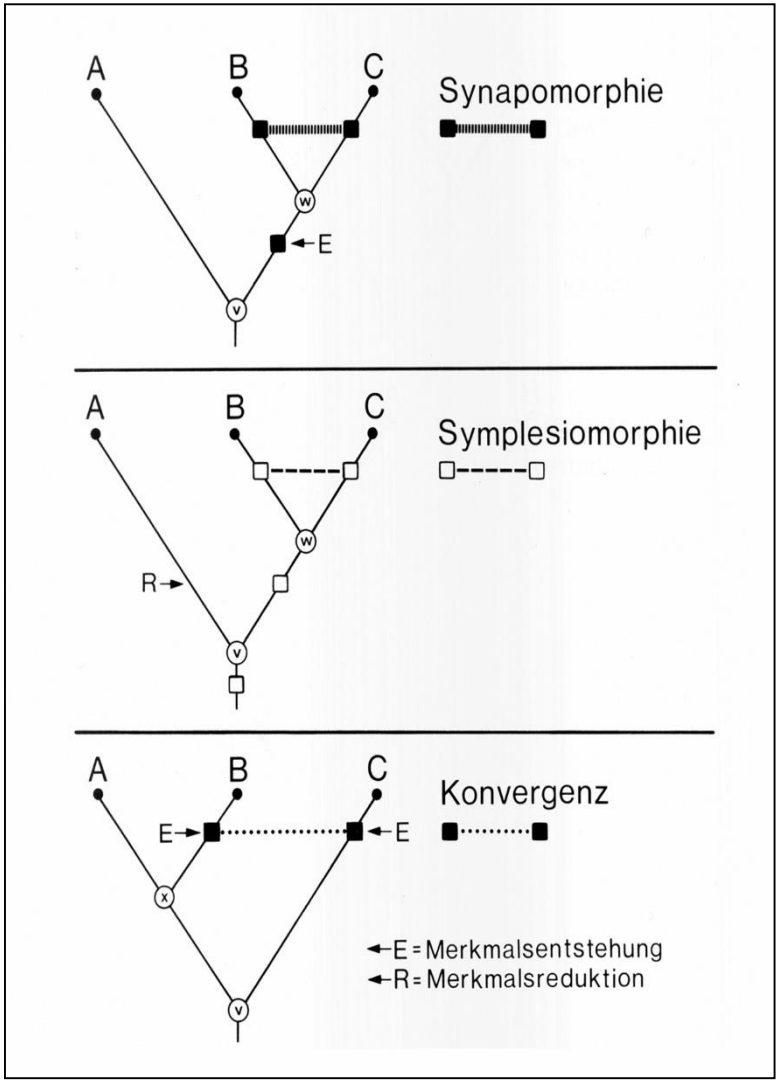
Phylogenetische Systematisierung

1. Sauropsida
   - 1.1. Lepidosauria
     - 1.1.1. Rhynchocephalia
     - 1.1.2. Squamata
   - 1.2. Archosauromorpha
     - 1.2.1. Chelonia
     - 1.2.2. Archosauria
       - 1.2.2.1. Crocodilia
       - 1.2.2.2. Aves
2. Mammalia

Einführung in die phylogenetische Systematik

- **Konsequente Widergabe von Artspaltungen aus früheren Stammarten**





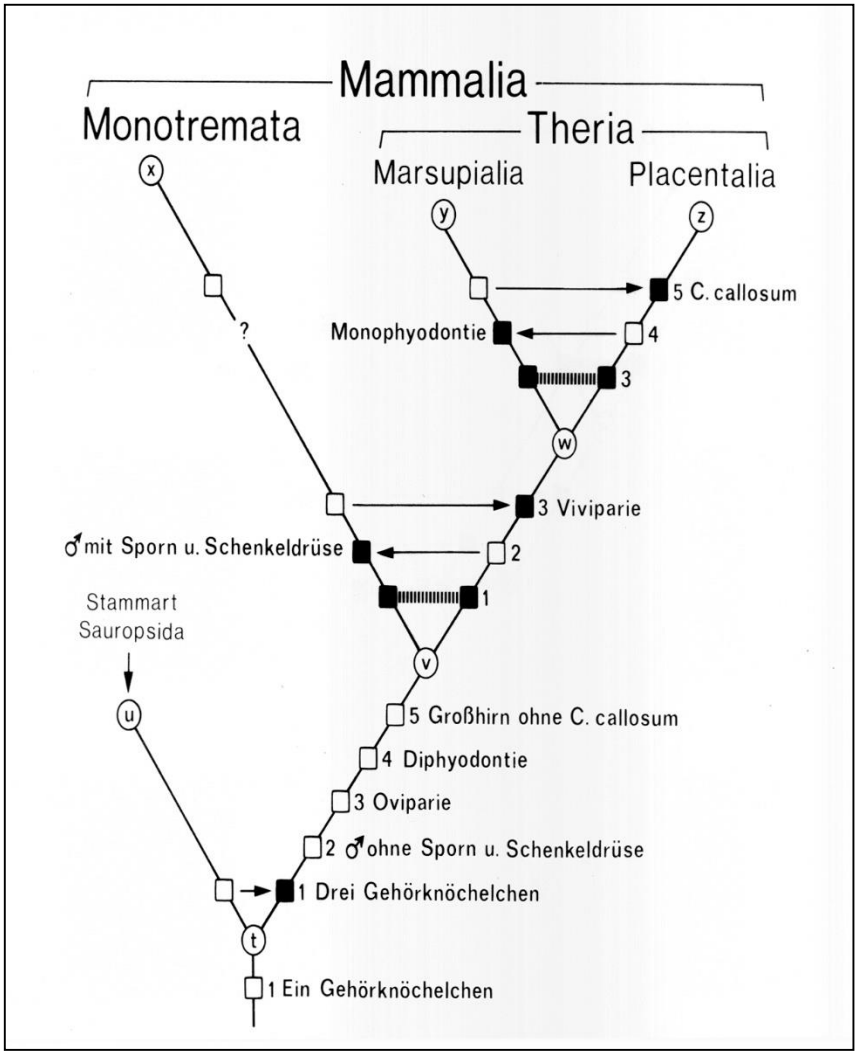
Parsimonie-Prinzip:

4 Merkmale von B + C

begründen diese als Adelphotaxa

Drei Möglichkeiten evolutiver Übereinstimmungen

Einführung in die phylogenetische Systematik



- **Hennigs Forderung:**

Taxa „monophyletisch“ (holophyletisch)

monophyletisch s.l. =

- Unmittelbare *oder* irgendeine frühere Stammart

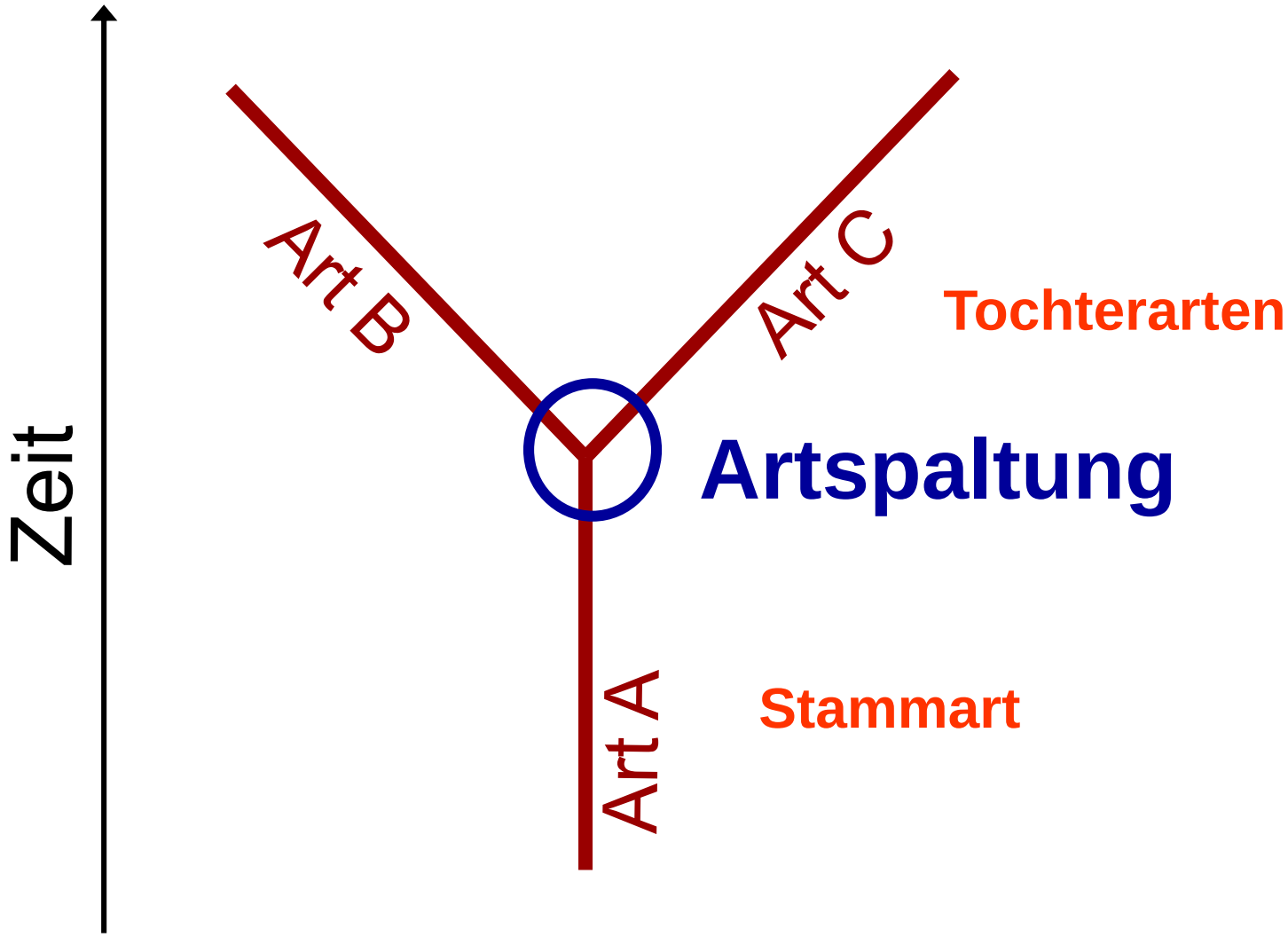
holophyletisch =

- **unmittelbare Stammart**
- **muß sämtliche Folgearten enthalten**

Suche nach Monophyla

- monophyletische Schwestergruppen

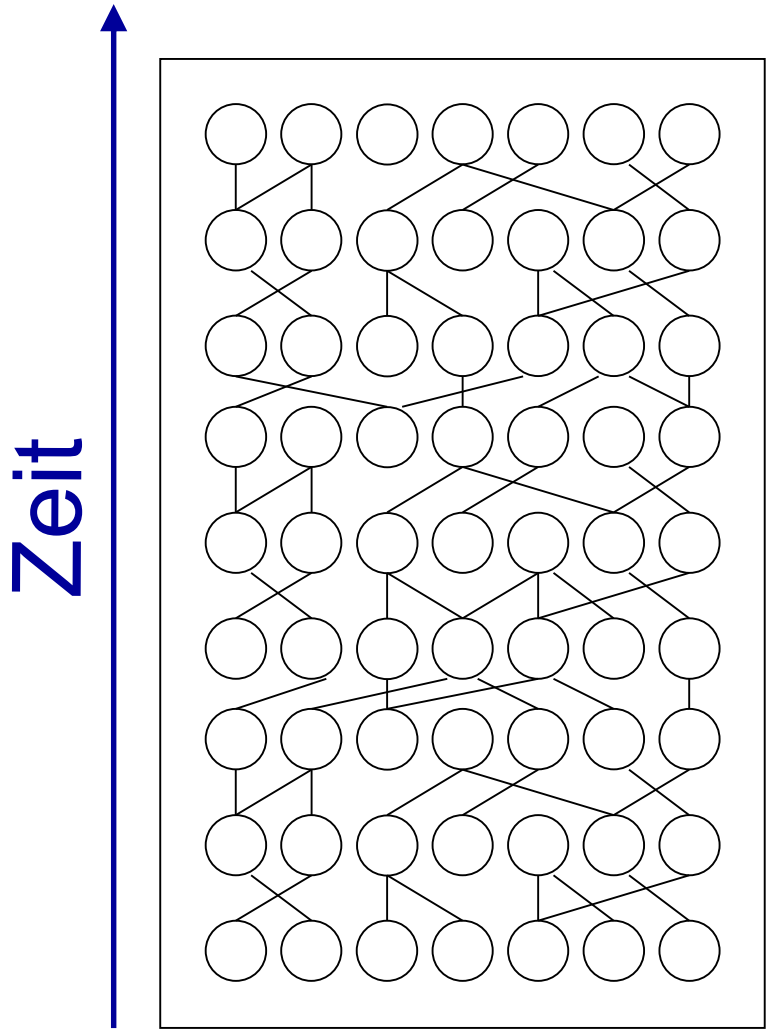
- keine Paraphyla



Aus einer Stammart entstehen zwei Tochterarten

Einführung – Der Artenbildungsvorgang als Grundlage

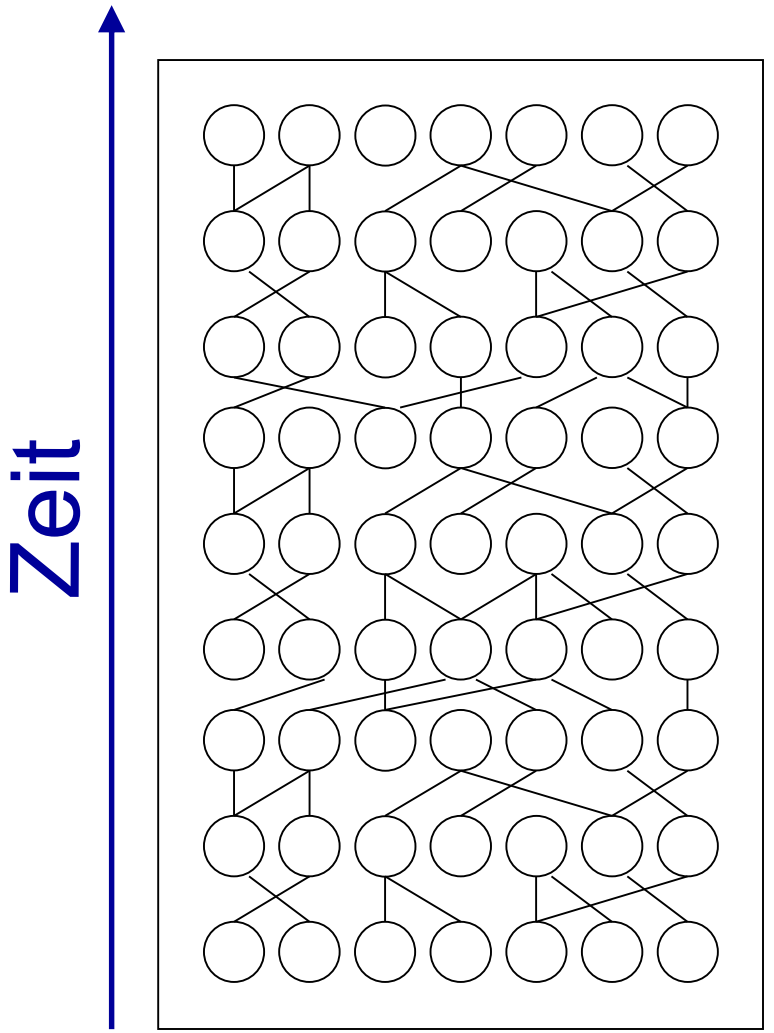
- **Was ist eine Art ?**

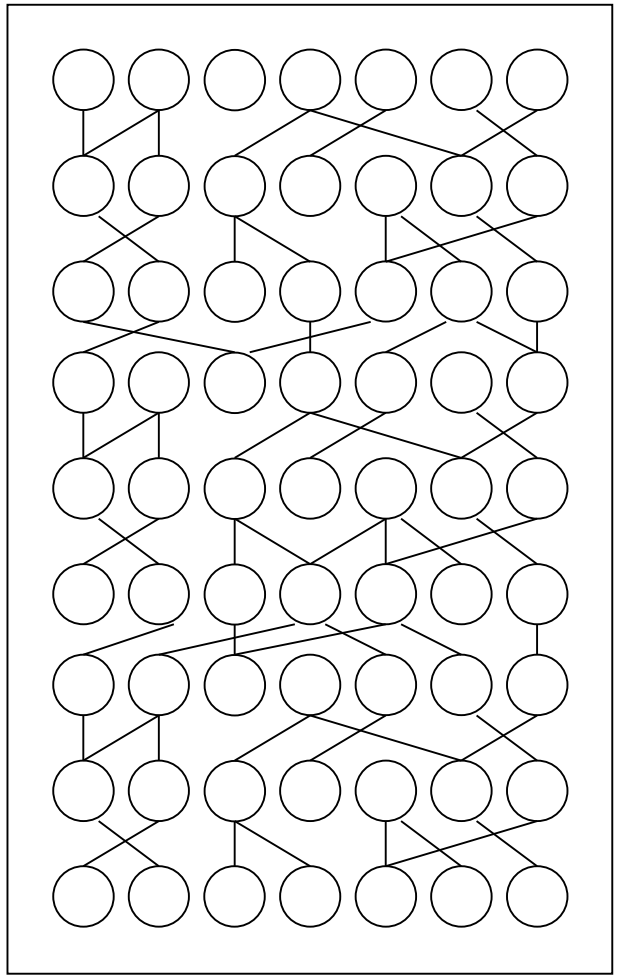


eine **Art** ist die Summe aller Individuen, die sich fortpflanzen und fruchtbare Nachkommen hervorbringen.

Einführung

- **Wie grenzen sich zwei Arten gegeneinander ab?**

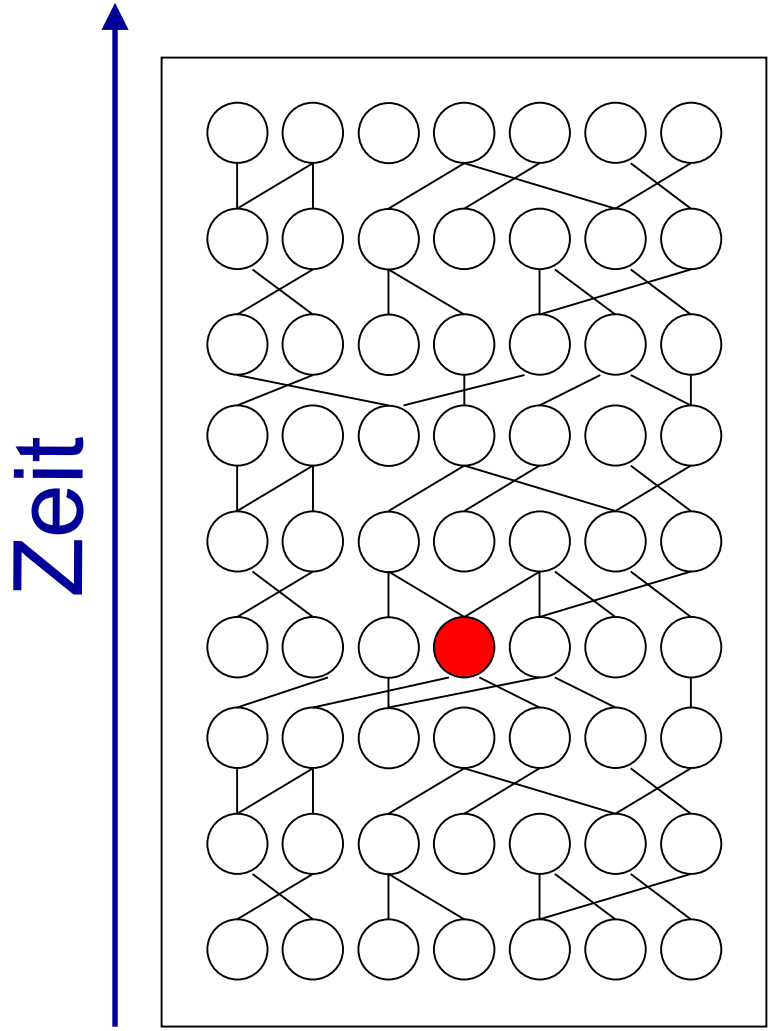




Zwischen 2 Arten findet keine Fortpflanzung statt

Einführung

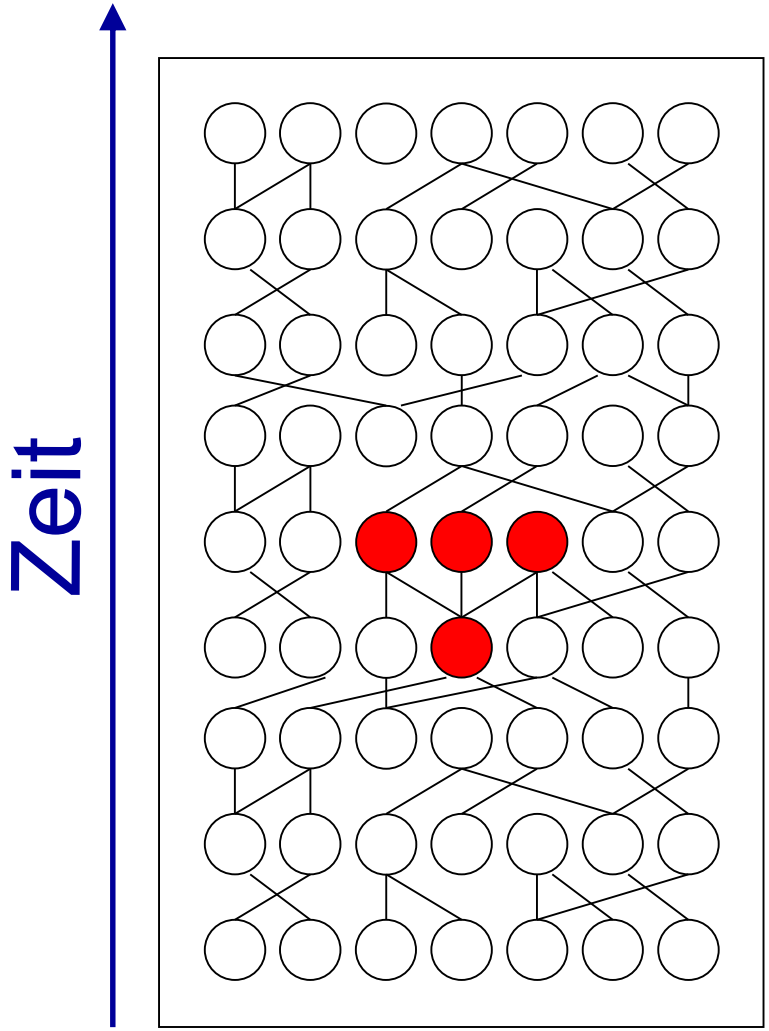
- **Artliche Verschiedenheiten**



In einer Art tritt eine Mutation auf

Einführung

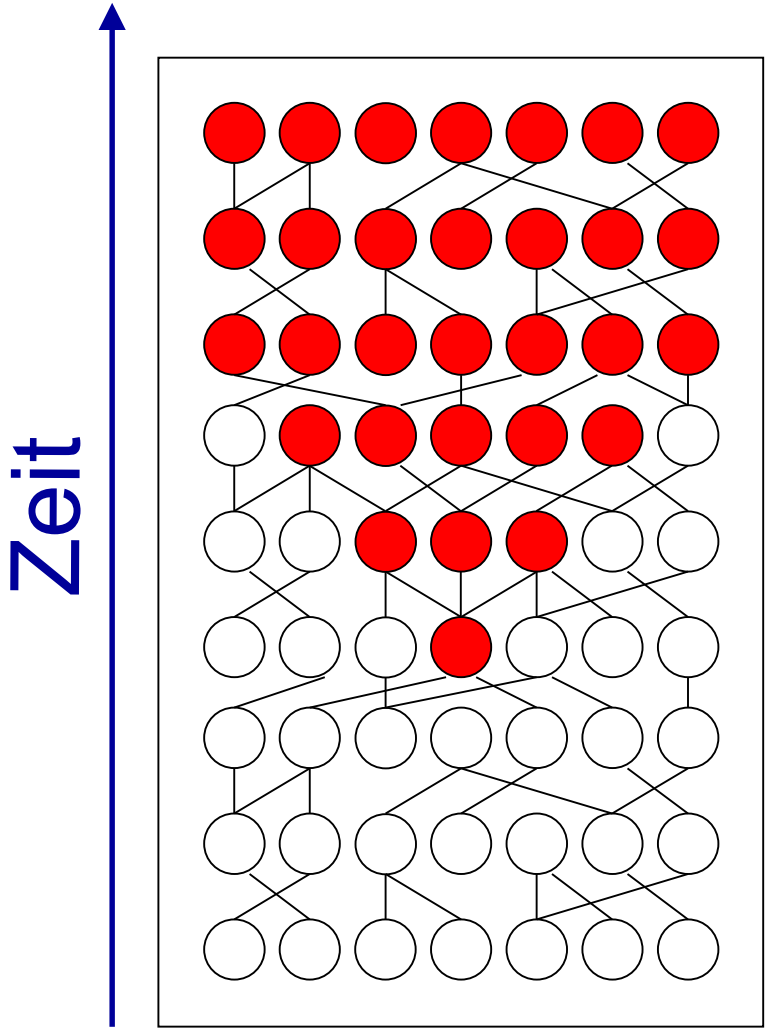
- **Vererbung der jeweiligen artlichen Merkmale**



In der nächsten Generation kann diese Mutation weitergegeben werden

Einführung

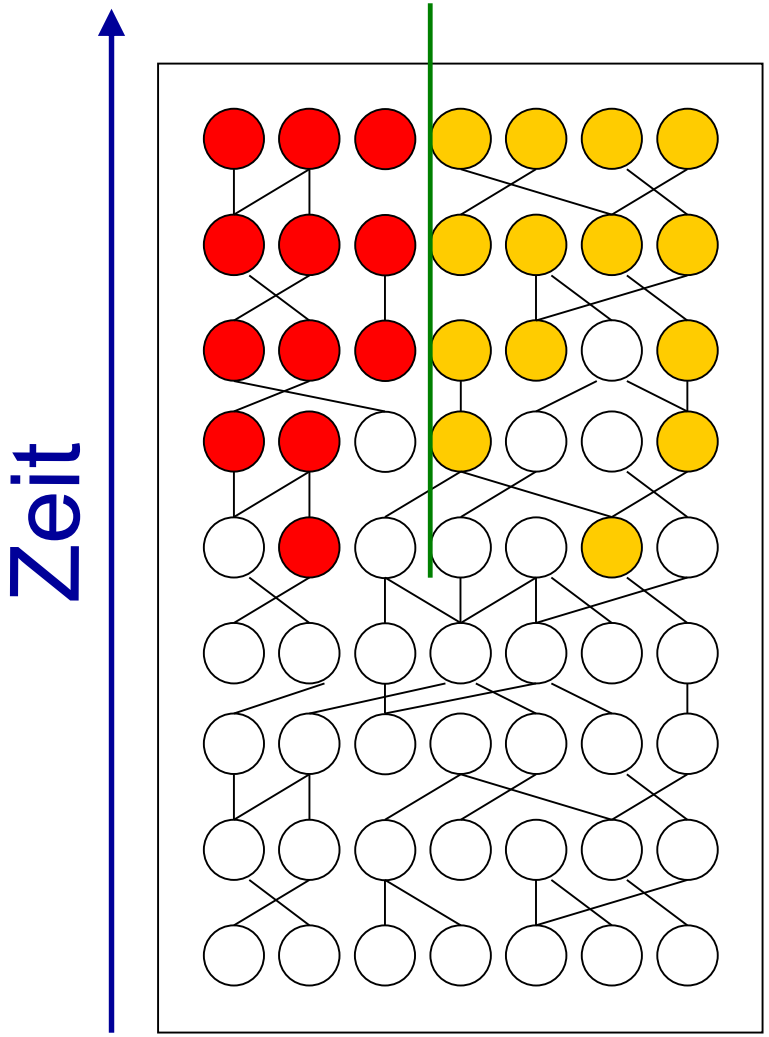
- **Das Merkmal setzt sich in der Population durch**



Arten ändern sich im Laufe der Zeit!

Einführung

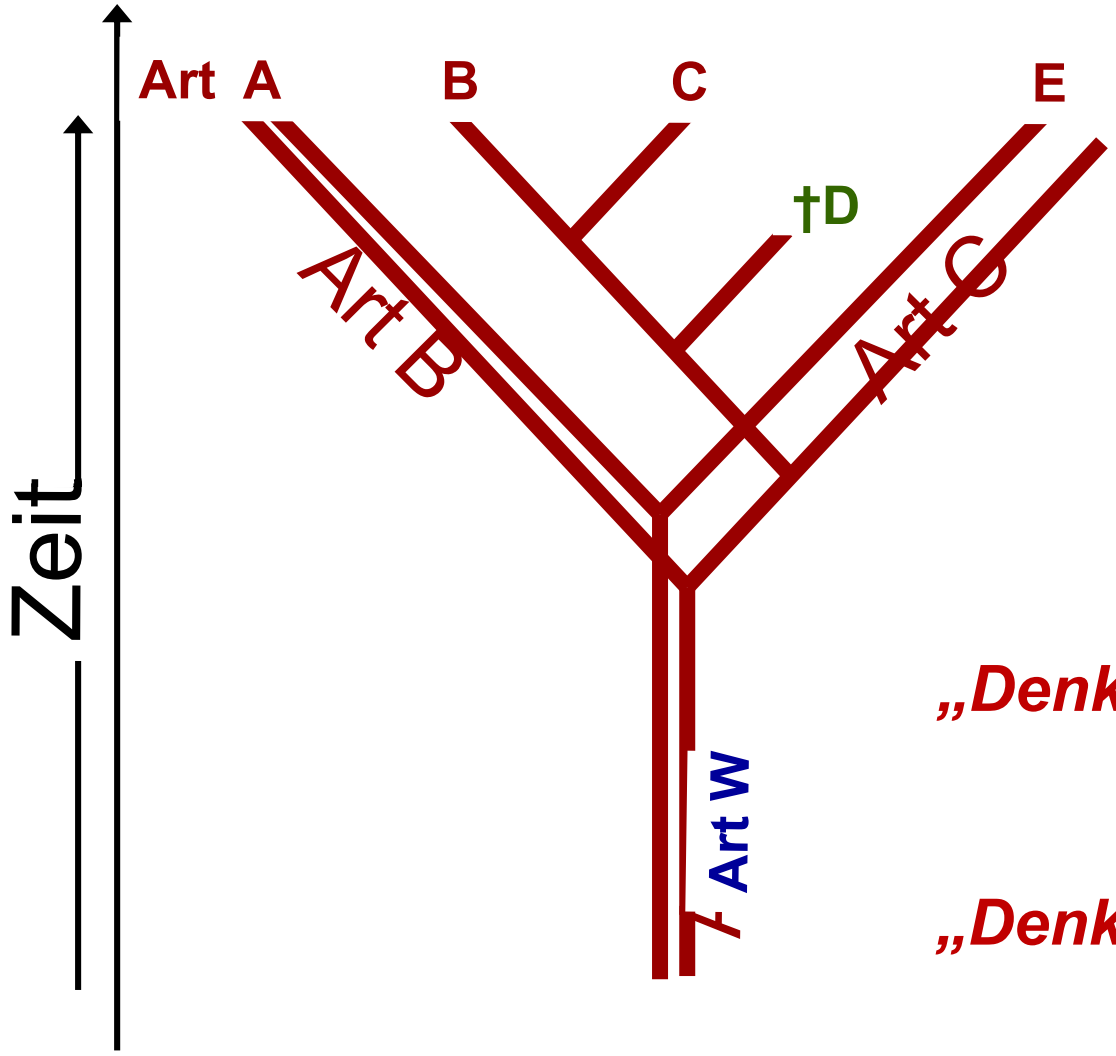
- **Isolation und Reproduktion**



Bei einer Isolation von zwei Populationen ändern sich die Teilpopulationen individuell.

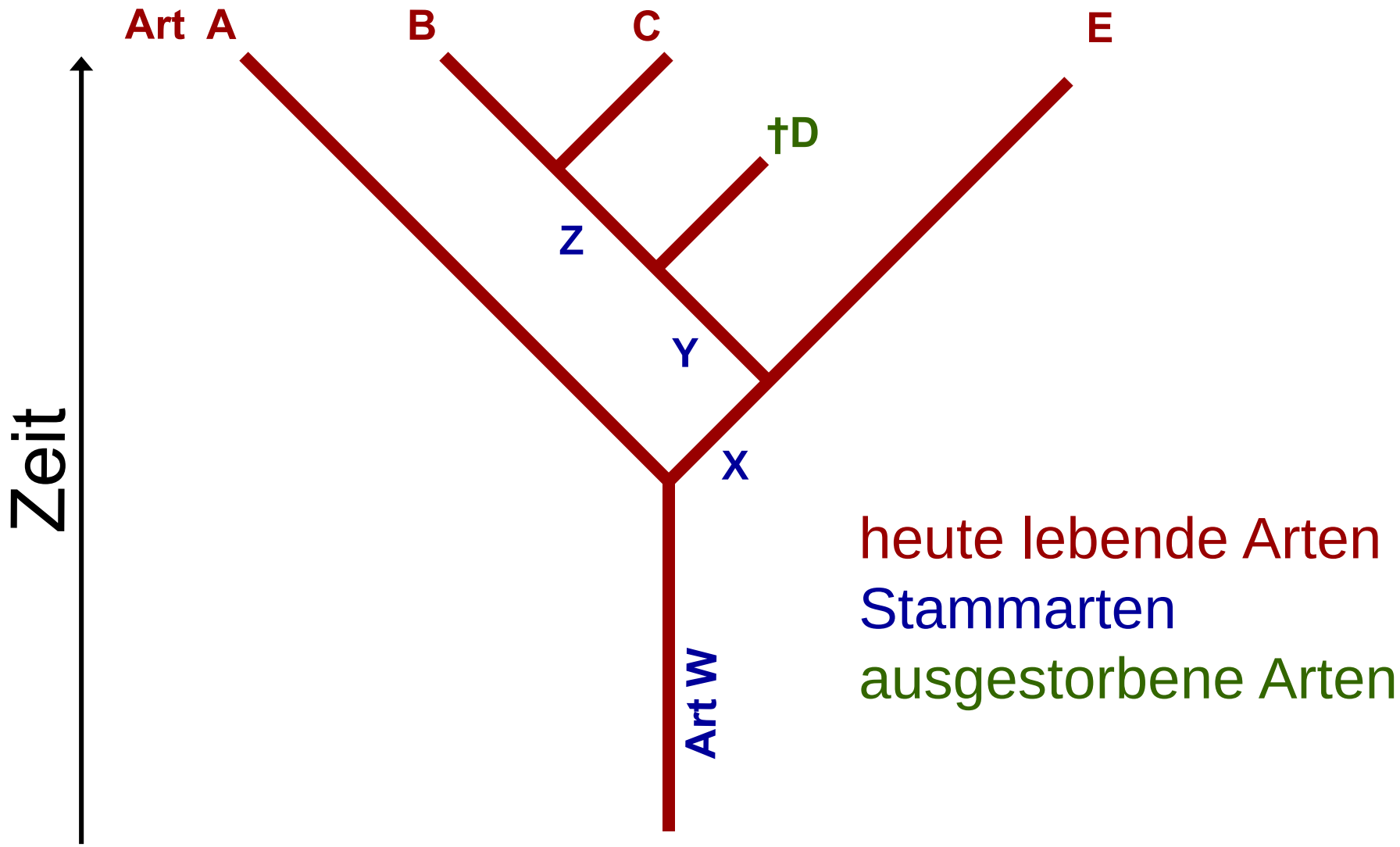
Wenn sich nach einer Zeit die Individuen aus beiden Populationen nicht mehr reproduzieren können, sind zwei Arten entstanden.

- **Mikroevolutions-Prozess übersetzt in makroevolutives Muster**



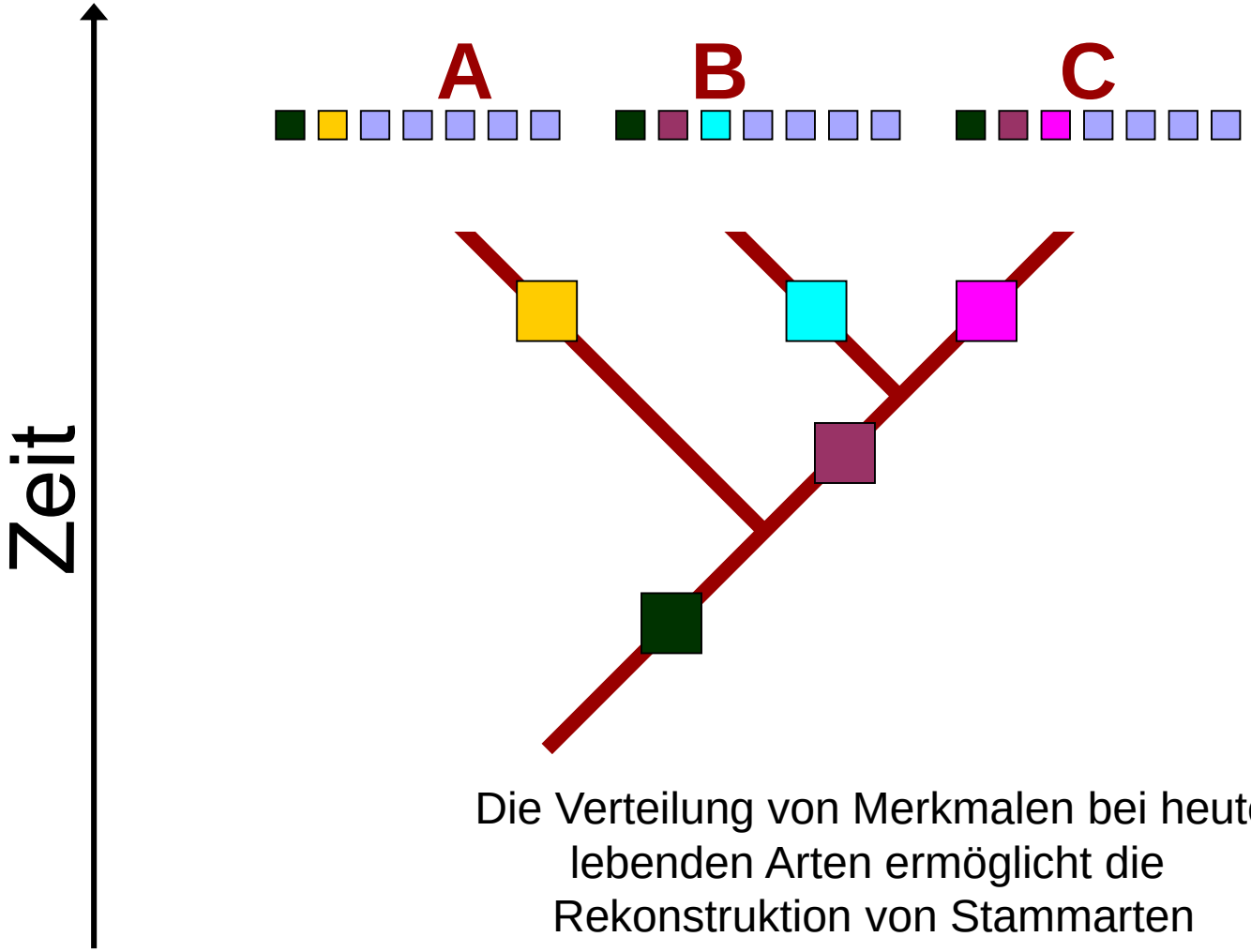
„Denken in Stammbäumen“

„Denken in Populationen“



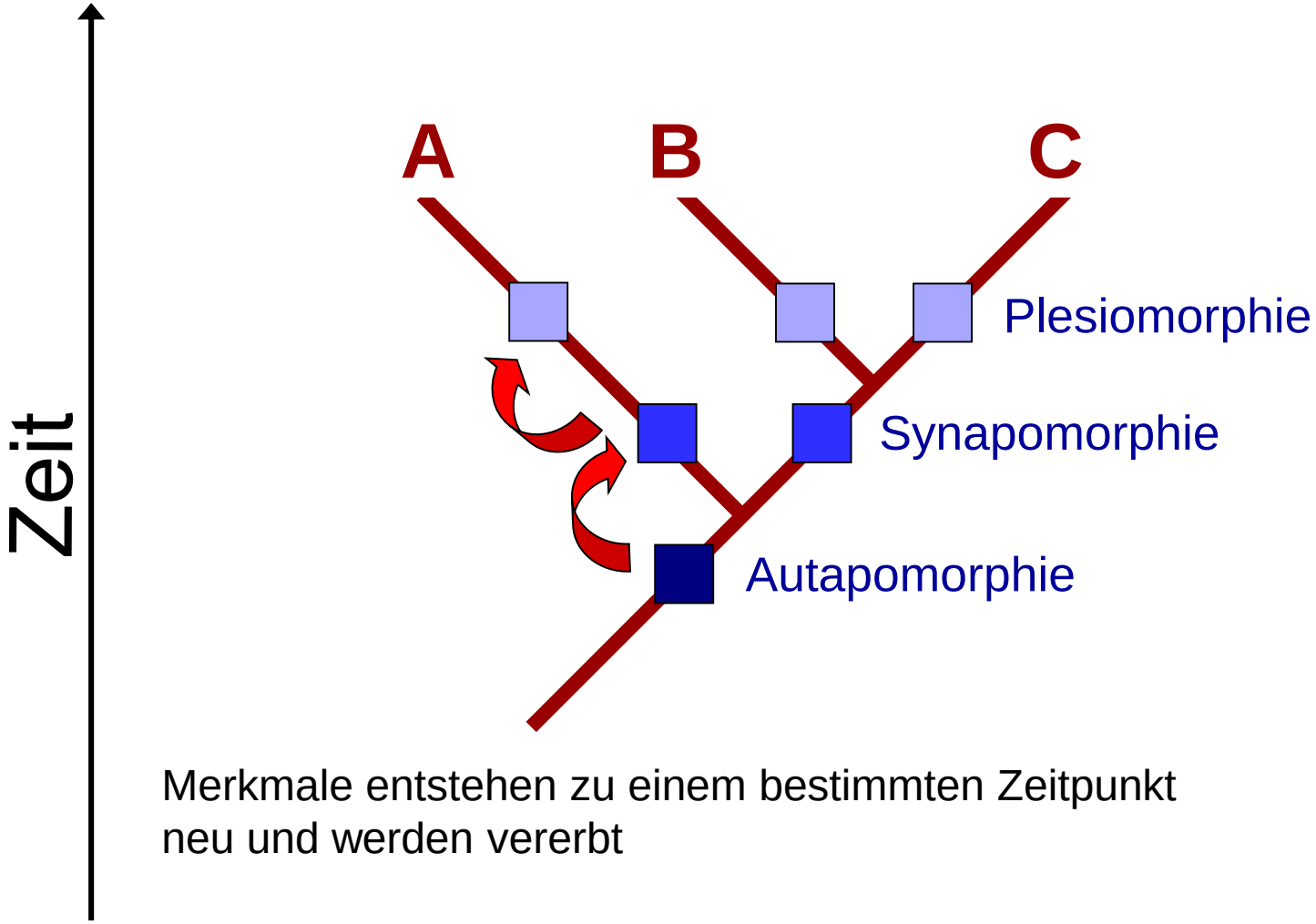
Stammbäume bestehen aus einer Vielzahl von Artspaltungen

- **Die Übersetzung des Vorgangs in die Kladistik**



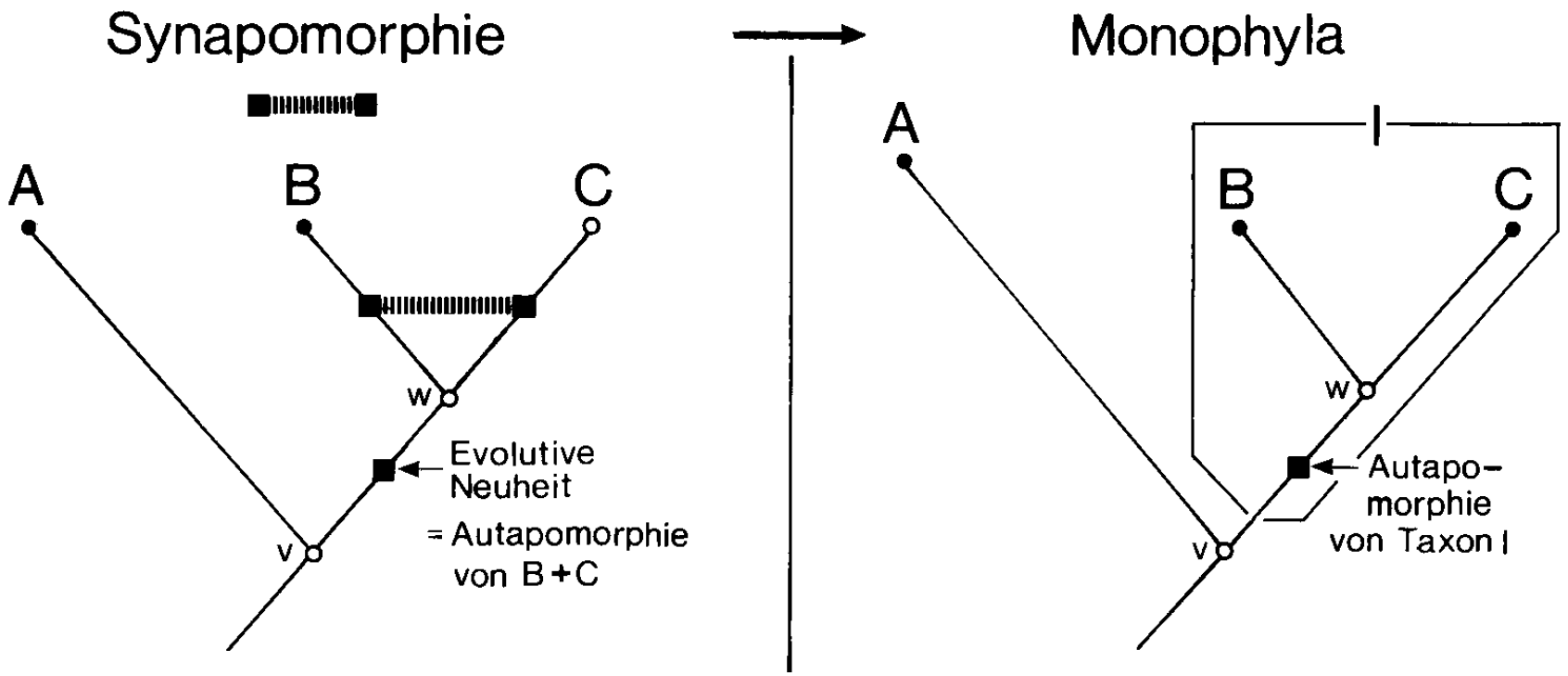
Die Verteilung von Merkmalen bei heute lebenden Arten ermöglicht die Rekonstruktion von Stammarten

- **Die Übersetzung des Vorgangs in die Kladistik**

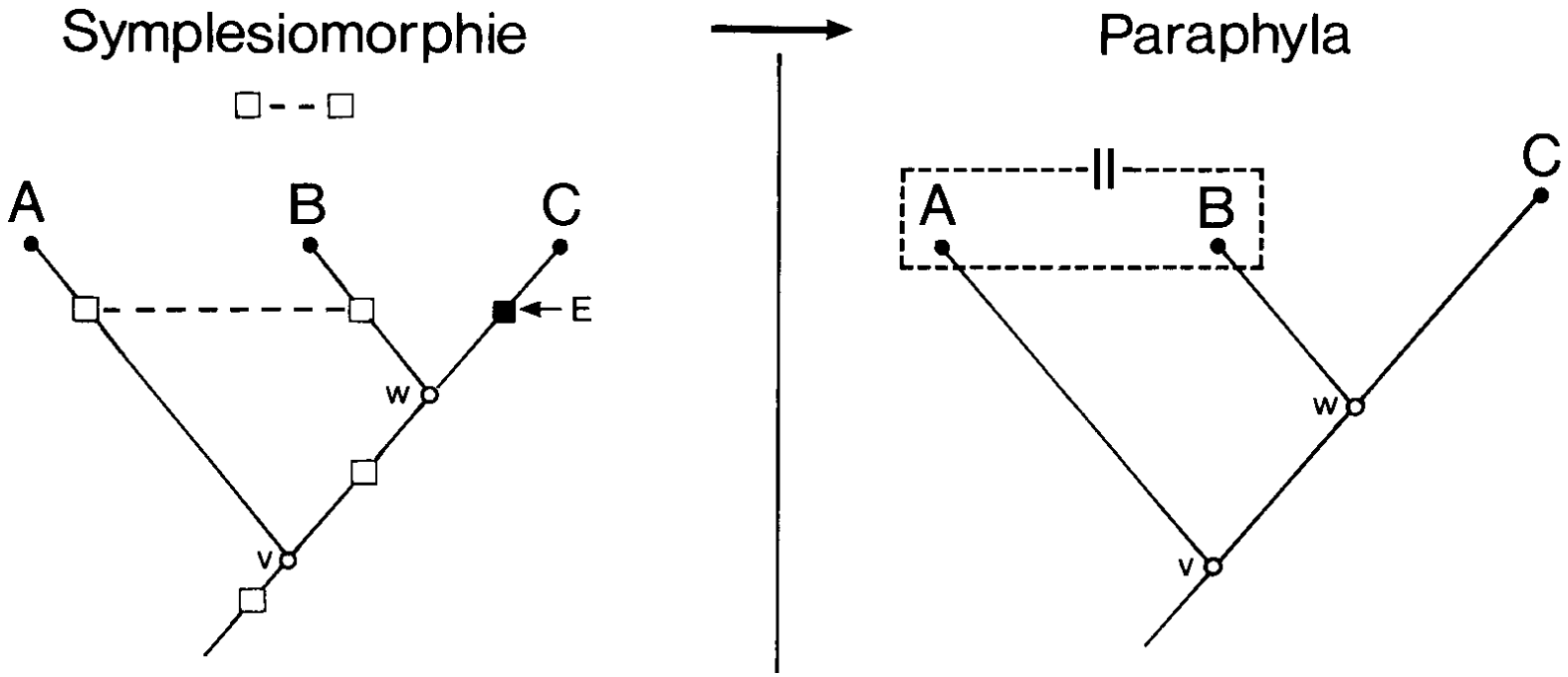


Merkmale entstehen zu einem bestimmten Zeitpunkt neu und werden vererbt

- **Die wichtigsten Begriffe**

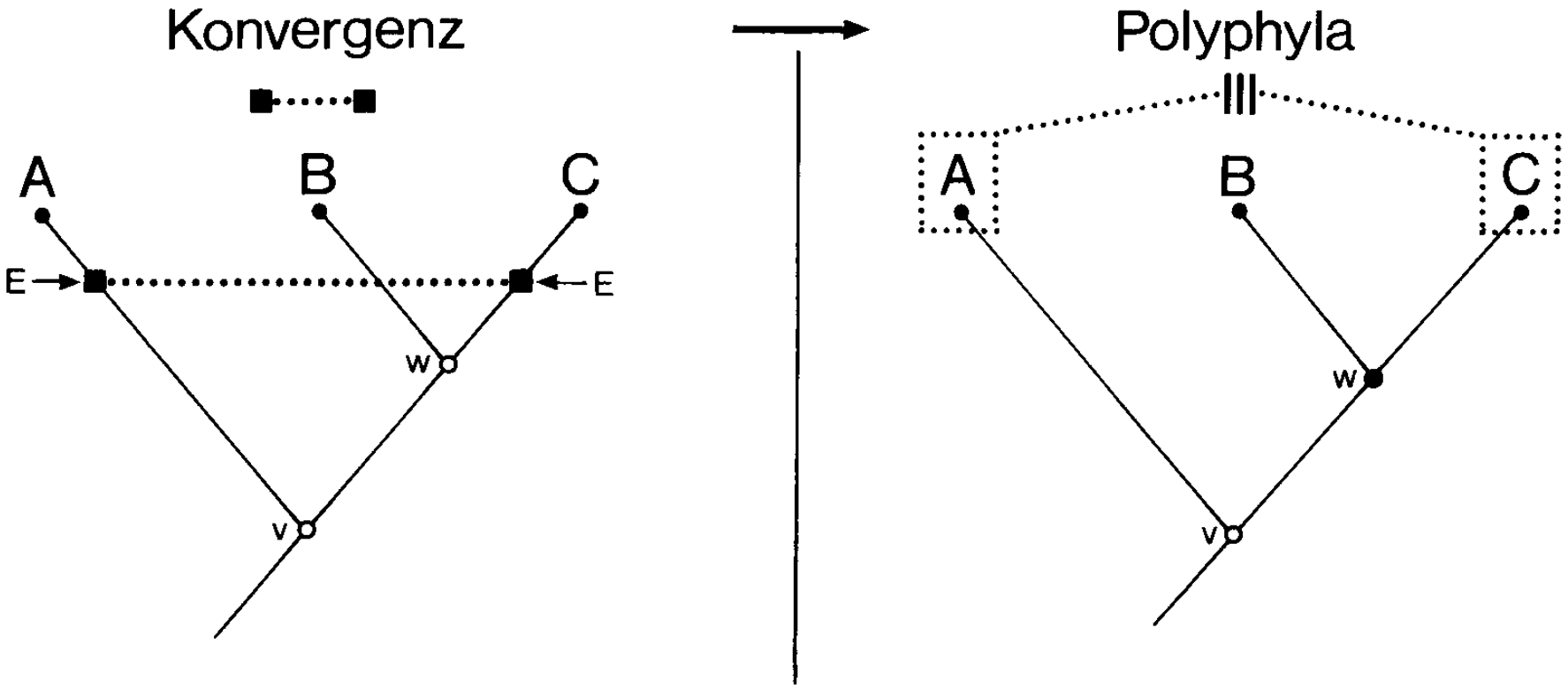


- **Die wichtigsten Begriffe**



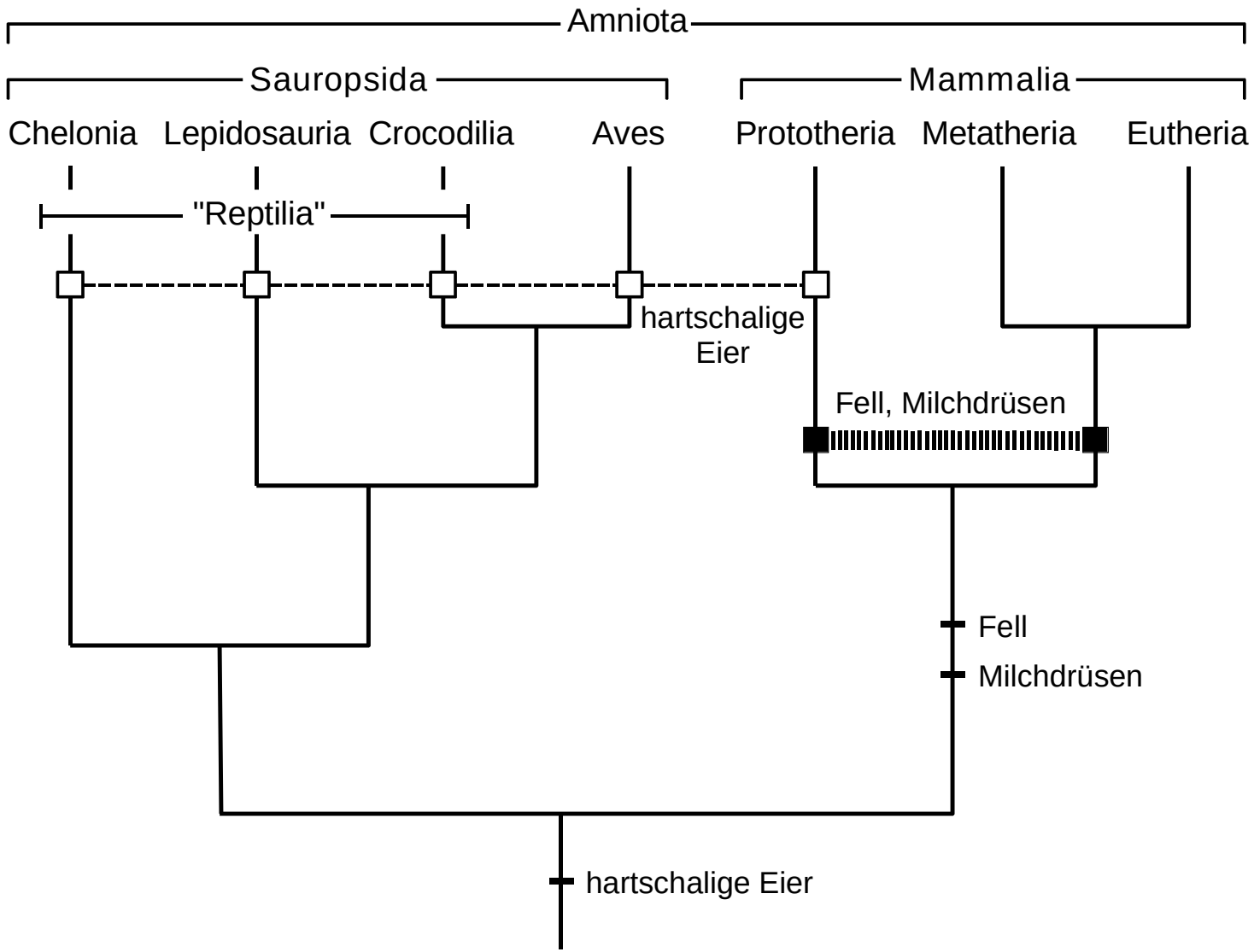
Einführung in die phylogenetische Systematik

- **Die wichtigsten Begriffe**

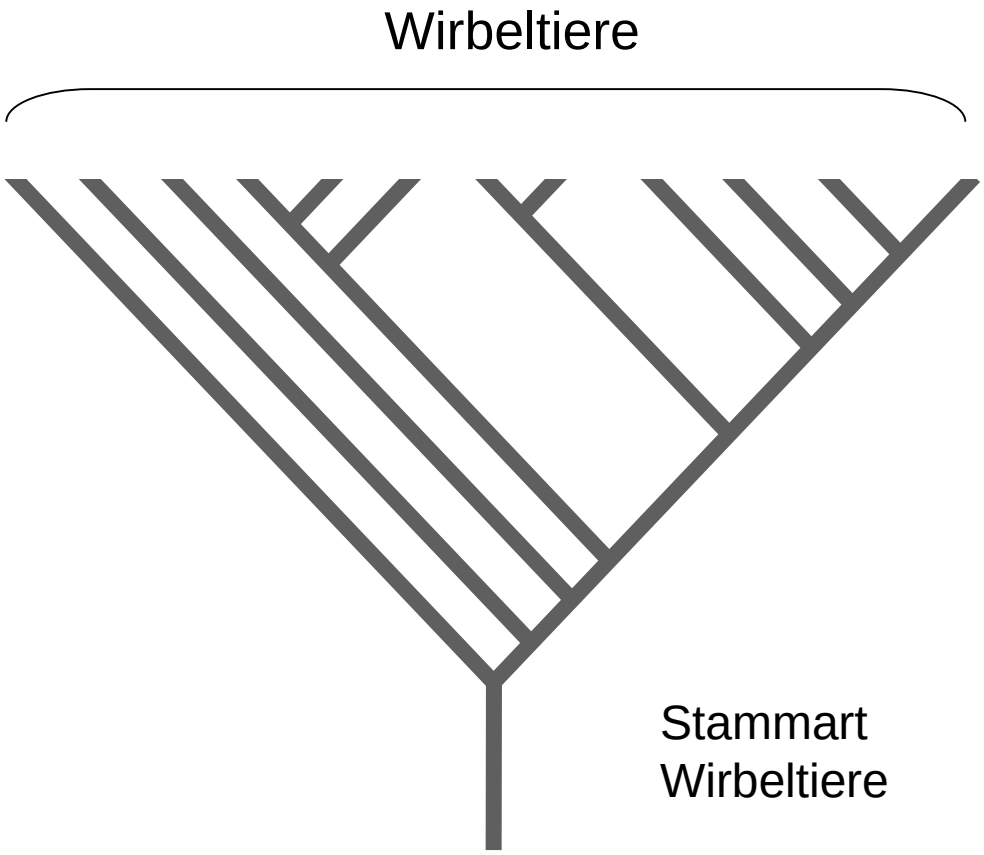


Einführung in die phylogenetische Systematik

- **Die wichtigsten Begriffe**



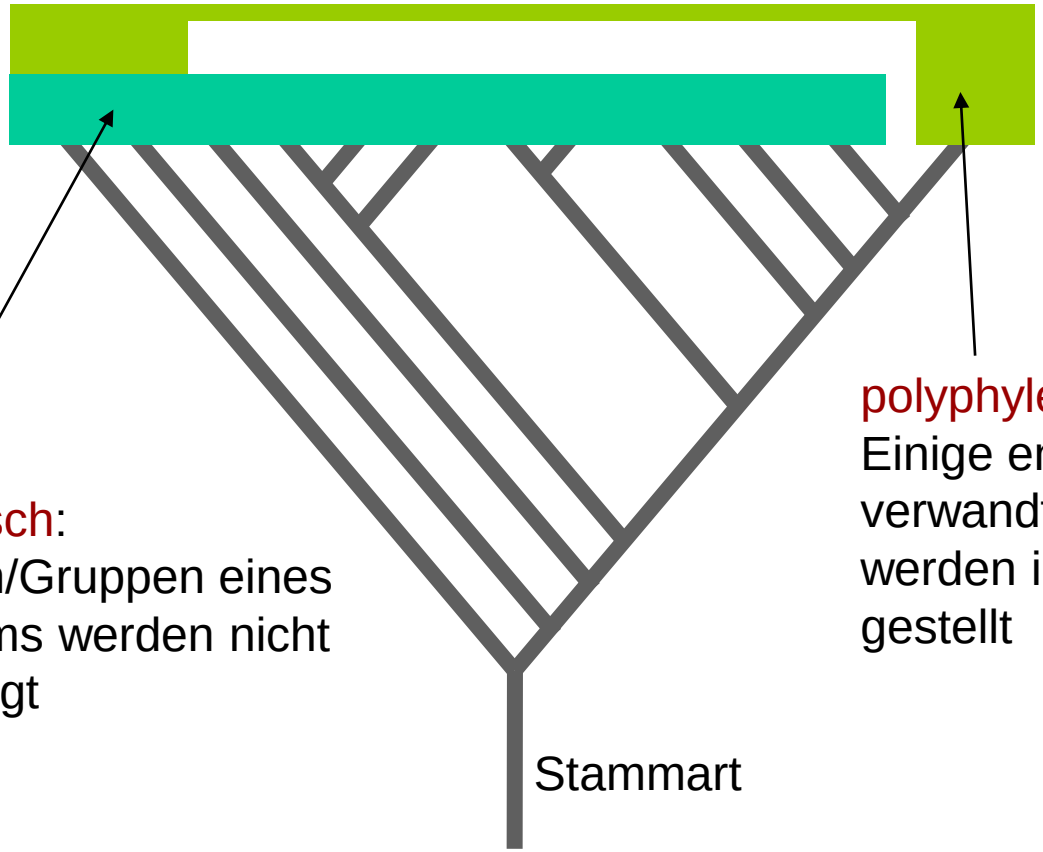
- **Monophyla**



Jede (vollständige) aus einer Stammart hervorgehende Gruppe wird benannt.
Solche Gruppen werden monophyletisch (Monophylum) genannt.

Einführung in die phylogenetische Systematik

- **Para- und Polyphyla**



paraphyletisch:
Einige Arten/Gruppen eines Monophylums werden nicht berücksichtigt

polyphyletisch:
Einige entfernt miteinander verwandte Arten/Gruppen werden in eine Gruppe gestellt

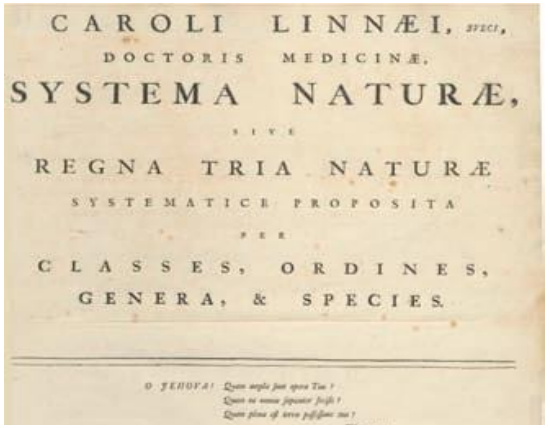
Manchmal werden nicht monophyletische Gruppen benannt. Solche paraphyletischen oder polyphyletischen Gruppen sind für die Systematik nicht hilfreich.

Zoologische Systematik – Zur Einführung

- **I - Grundbegriffe & Geschichte**

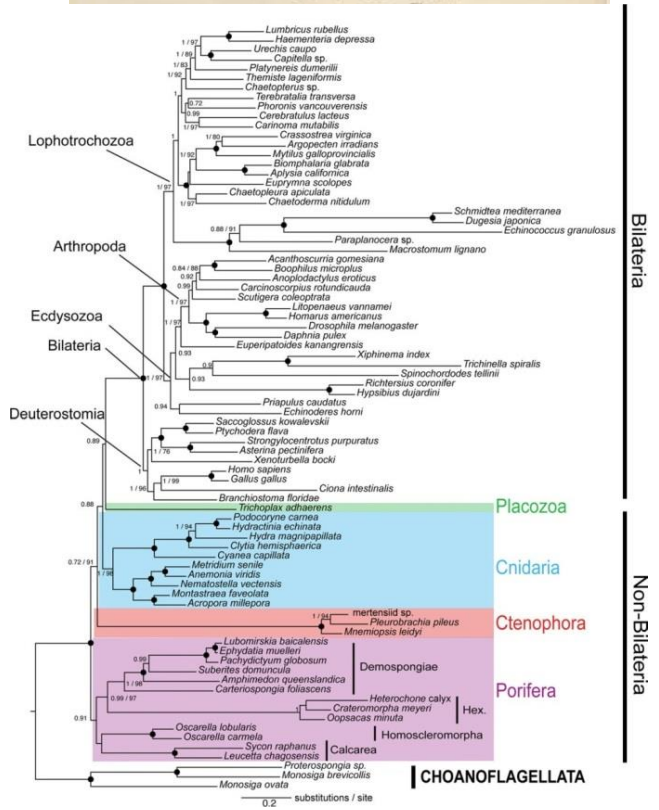
  Was ist eigentlich Systematik ?

  Wie geht das; warum betreiben wir sie ?


CAROLI LINNÆI, SVECI,
DOCTORIS MEDICINÆ,
SYSTEMA NATURÆ,
SIVE
REGNA TRIA NATURÆ
SYSTEMATICE PROPOSITA
PER
CLASSES, ORDINES,
GENERA, & SPECIES.

- **II – Systematische Zoologie**

  Das System der Tiere: Metazoa & Co.



Systematik und Stammbäume

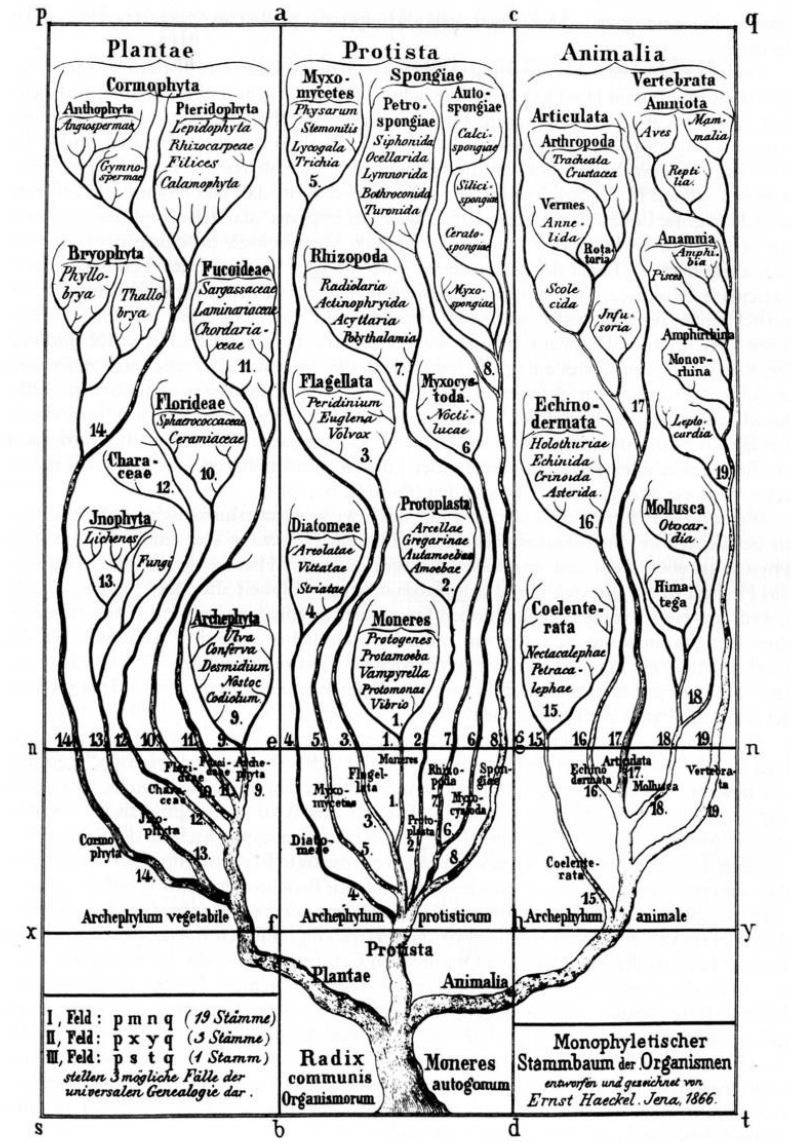
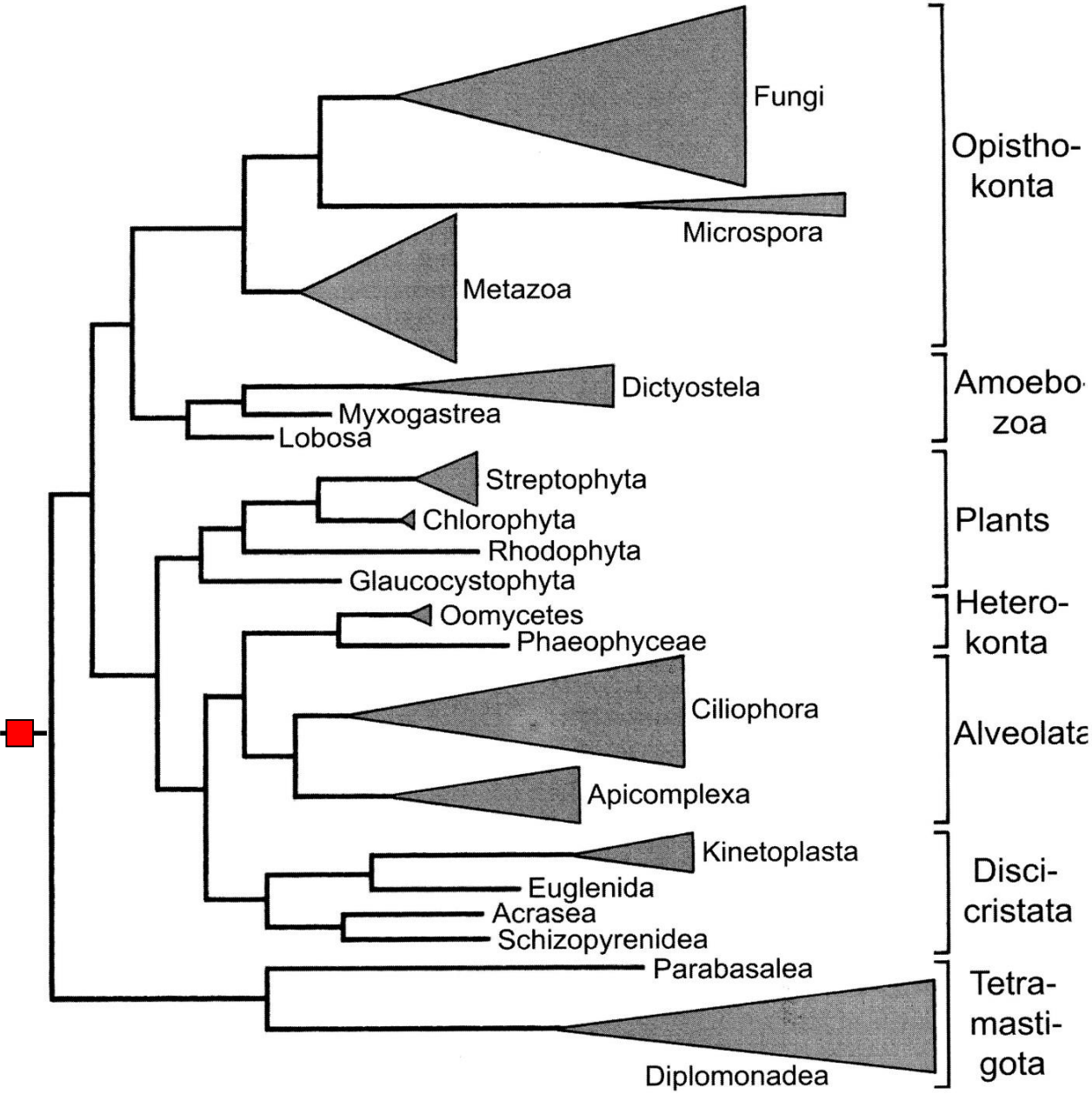


Abb. 4. Monophyletischer Stammbaum der Organismen von E. Haeckel aus seinem Werk „Generelle Morphologie der Organismen“ (1866).

Ein erster Überblick über die Organismen-Reiche

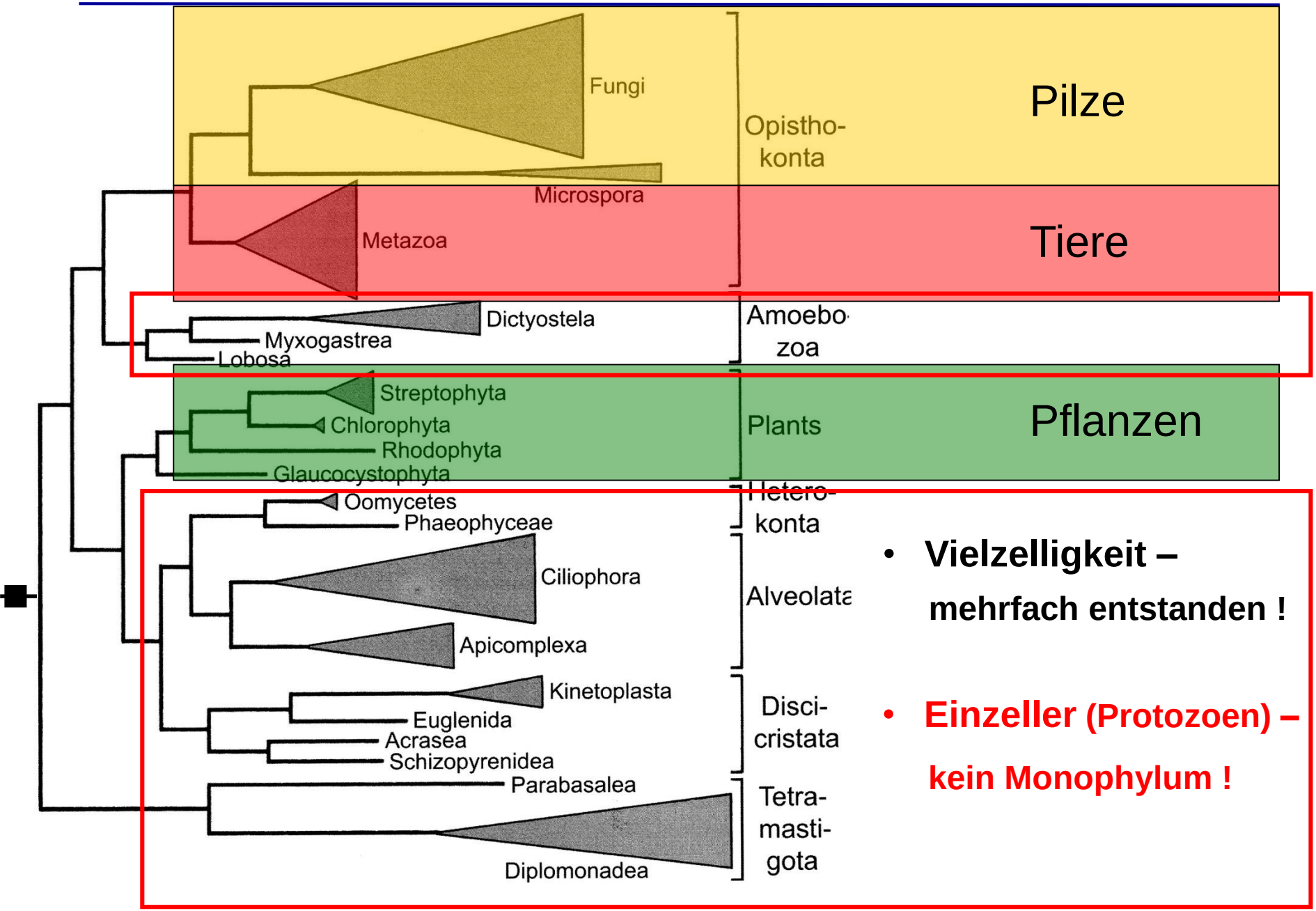


Stammbaum der Eukaryota

Autapomorphie:

- DNA ist in einem Zellkern konzentriert

Ein erster Überblick über die Organismen-Reiche

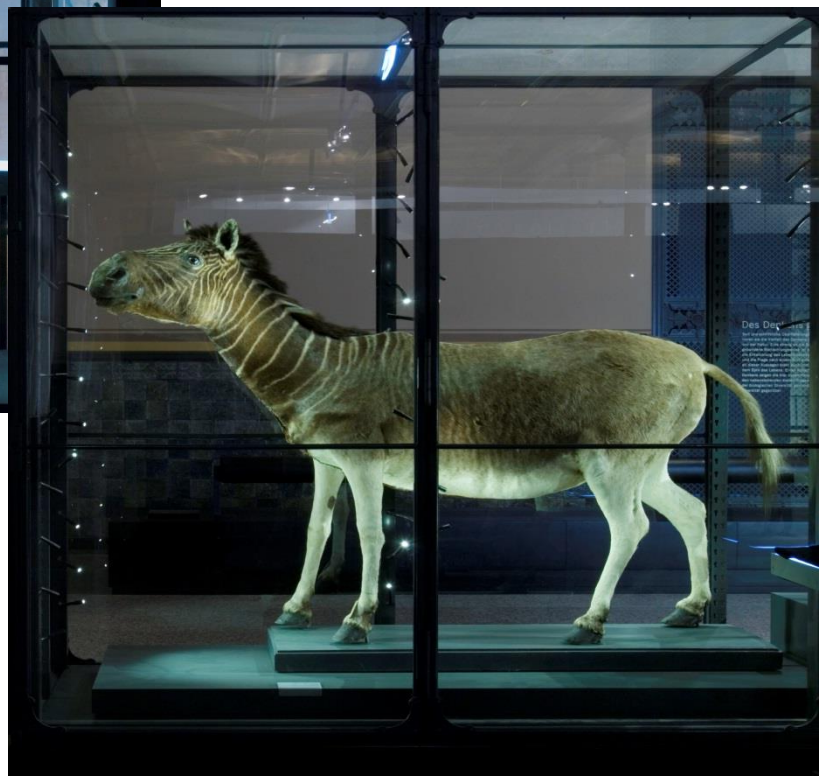


- **Vielzelligkeit – mehrfach entstanden !**
- **Einzeller (Protozoen) – kein Monophylum !**

Die verwirrende Vielfalt der Namen

Kleine Protisten – große Wirkung

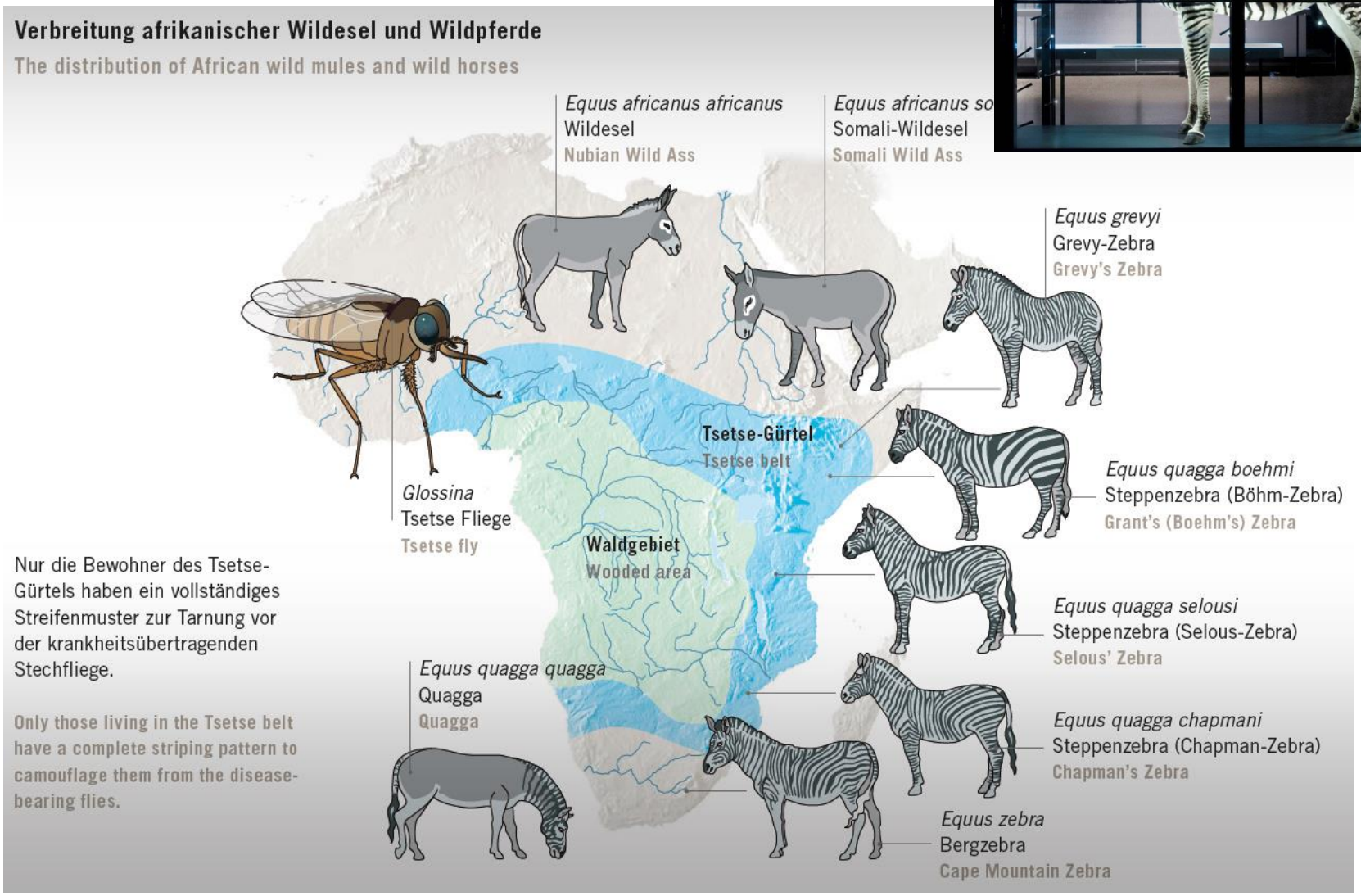
Warum das Zebra Streifen hat …



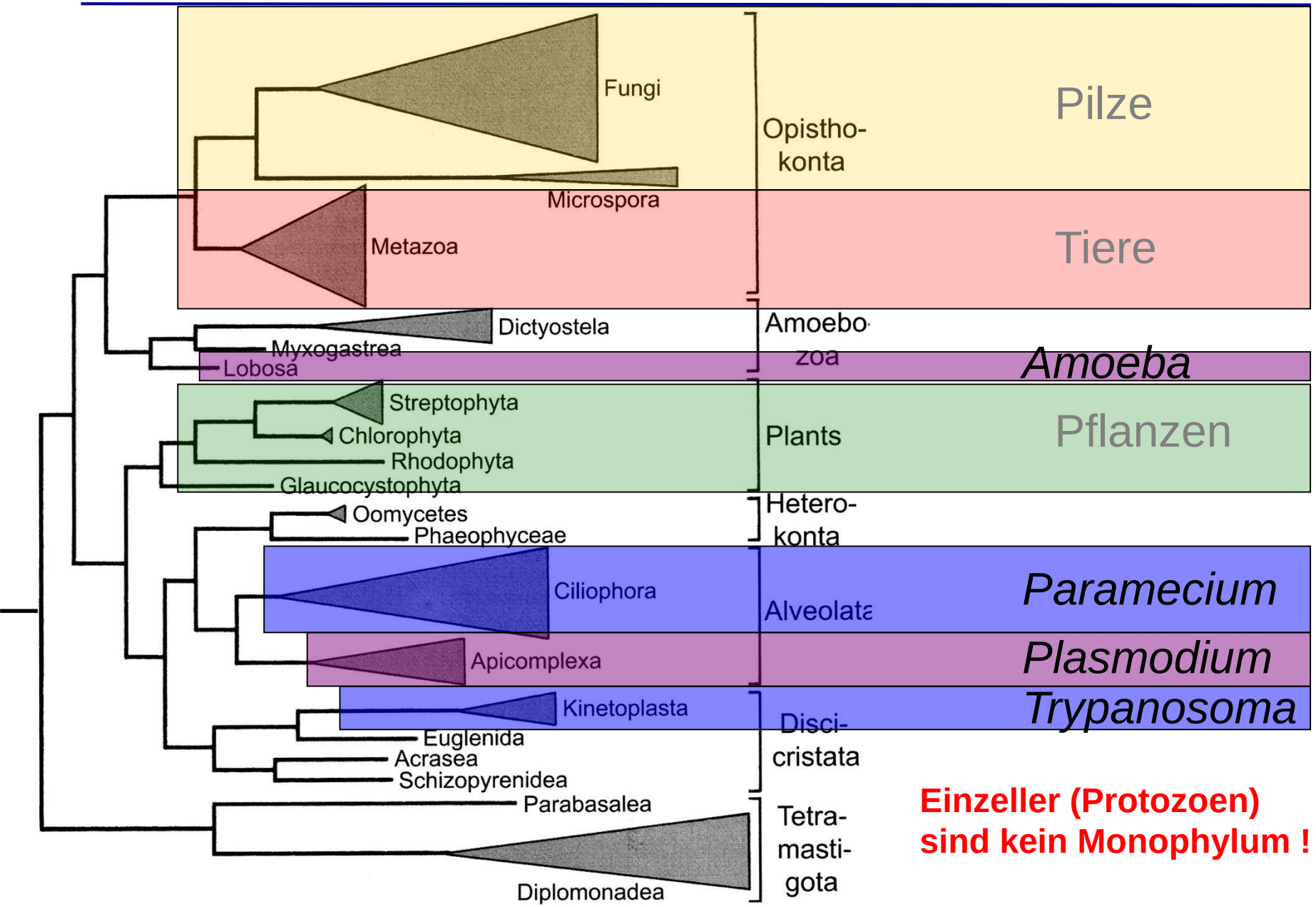
… und das Quagga sie wieder verlor

Kleine Protisten – große Wirkung

- **Warum das Zebra Streifen hat …**



Ein erster Überblick über die Organismen-Reiche

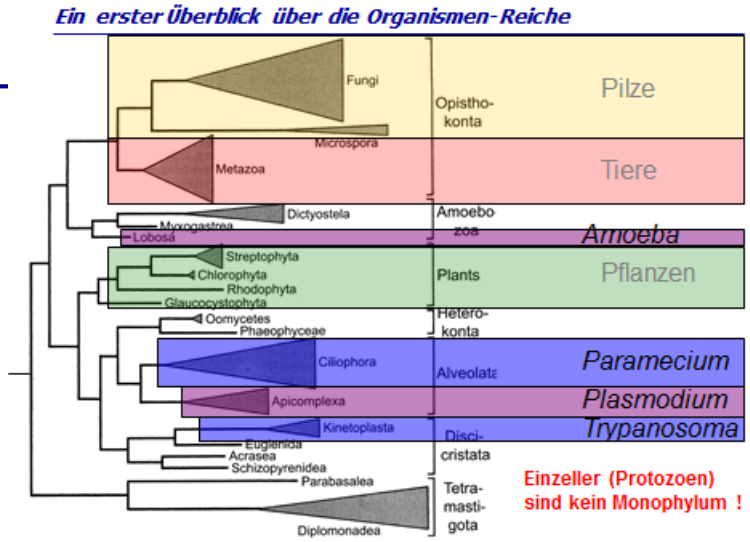


Einzeller (Protozoen)
sind kein Monophylum !

Protista

- **einzellige Eukaryota**

paraphyletische Stammgruppe der vielzelligen Metazoa, Pilze und Pflanzen



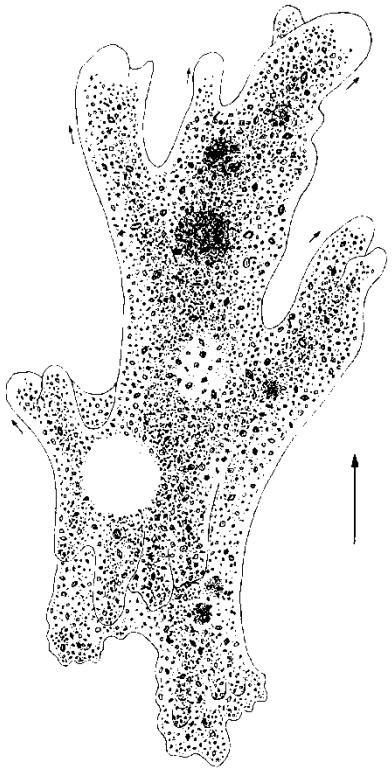
- autotrophe Protista: Protophyta

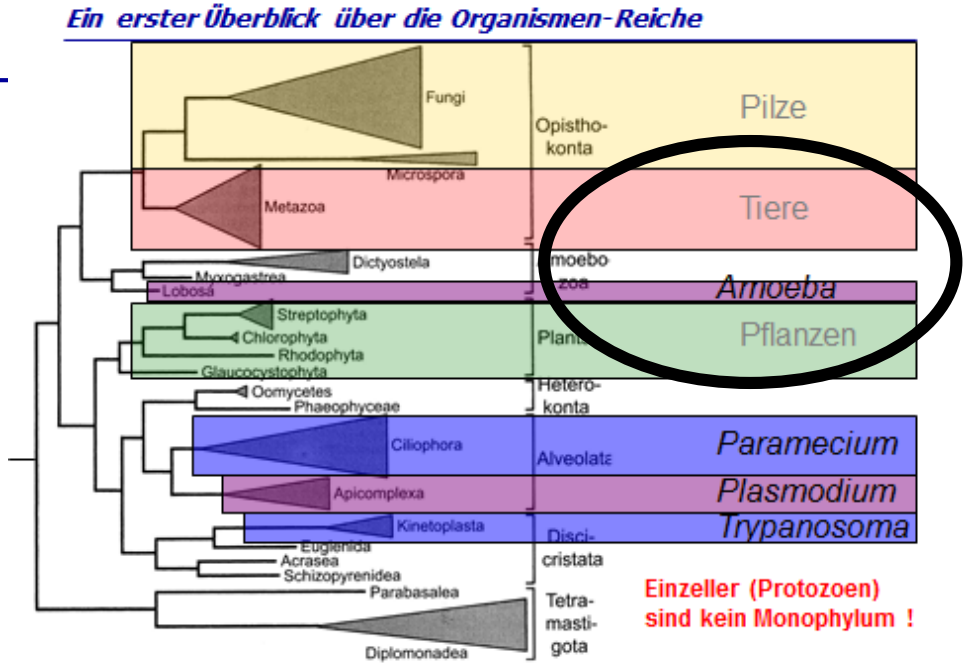
- heterotrophe Protista: Protozoa

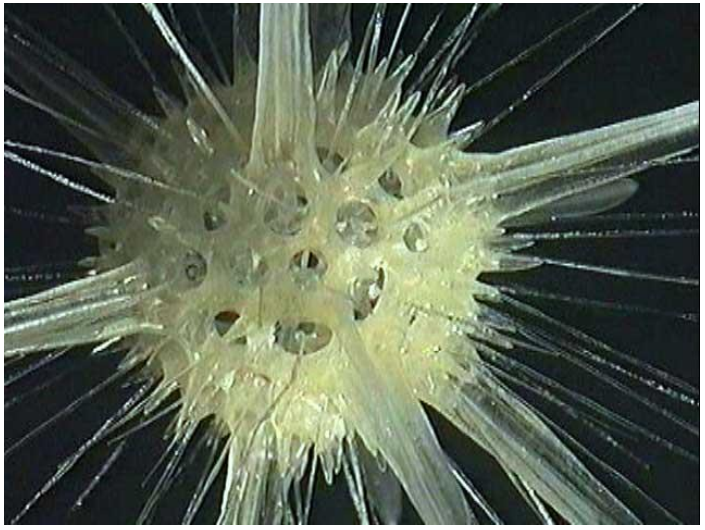
Protozoa

Rhizopoda

- *Amoeba proteus* (Amöben)
- Testacea (Thekamöben)
- Foraminifera
- Radiolaria



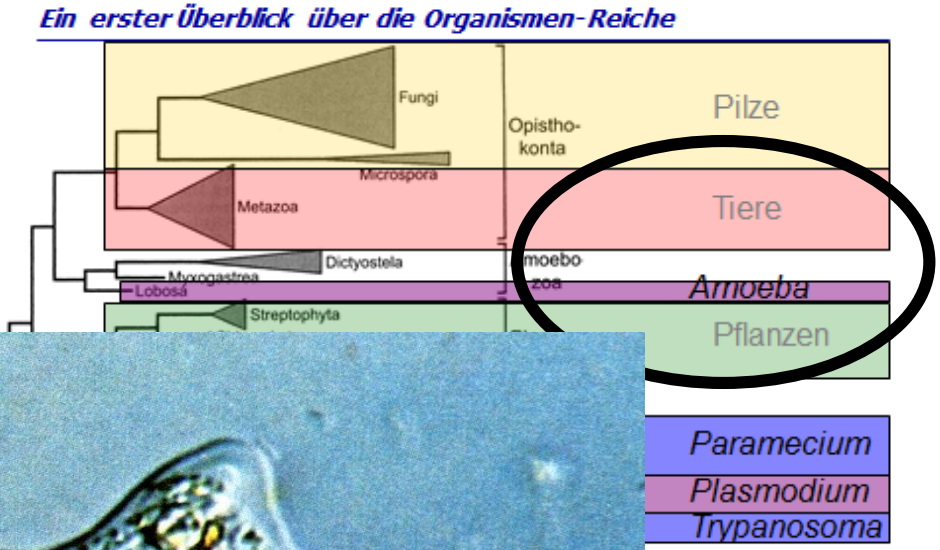


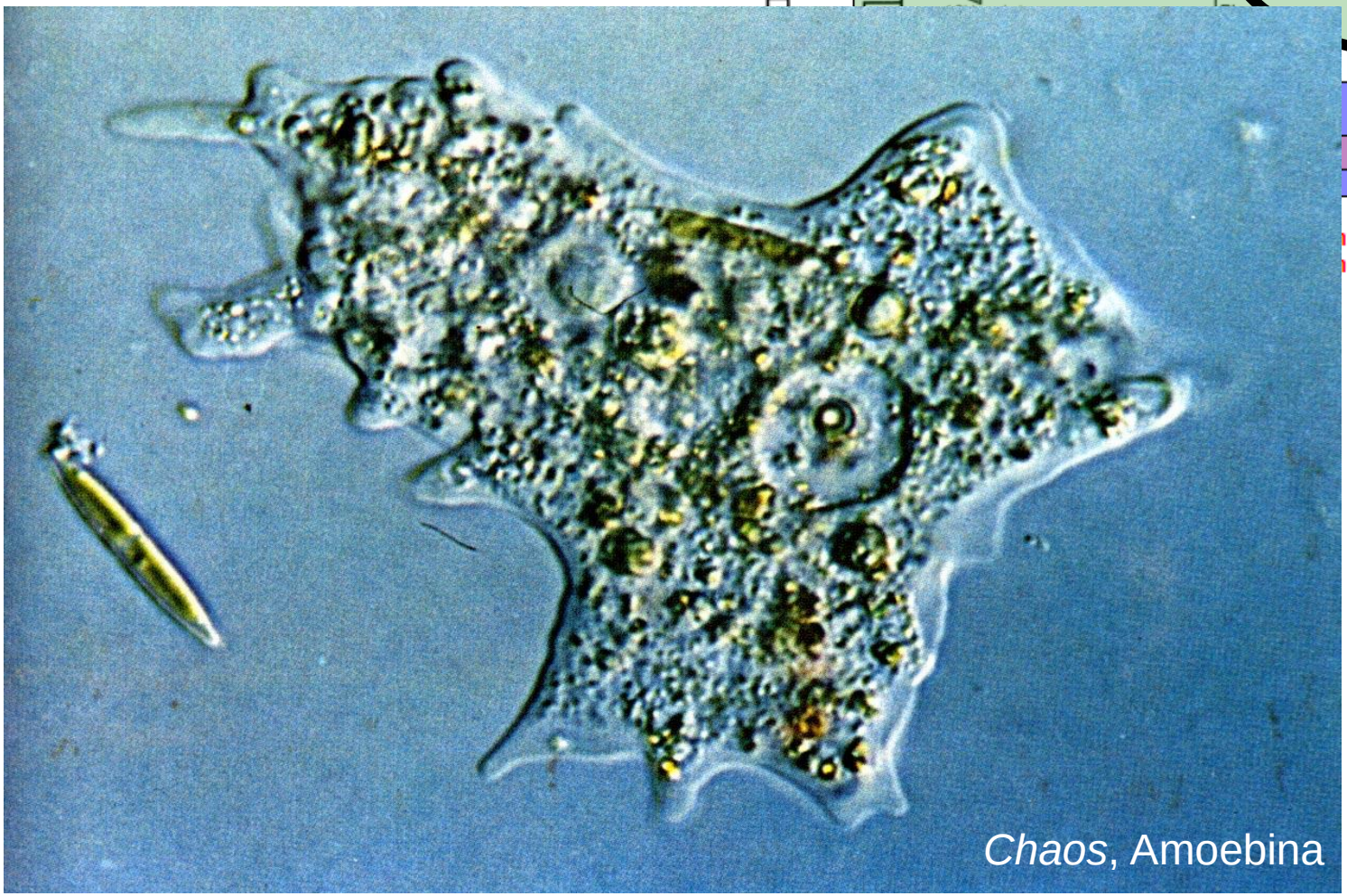


Protozoa

Rhizopoda

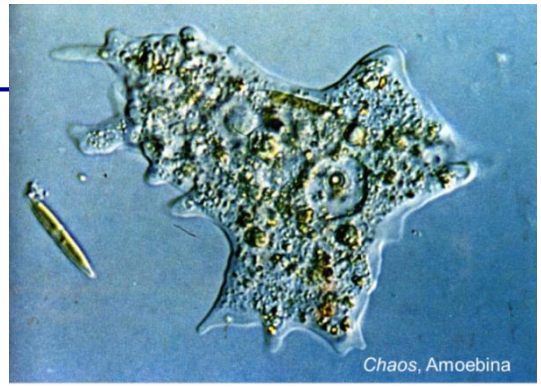
- ***Amoeba proteus*** **(Amöben)**





Chaos, Amoebina

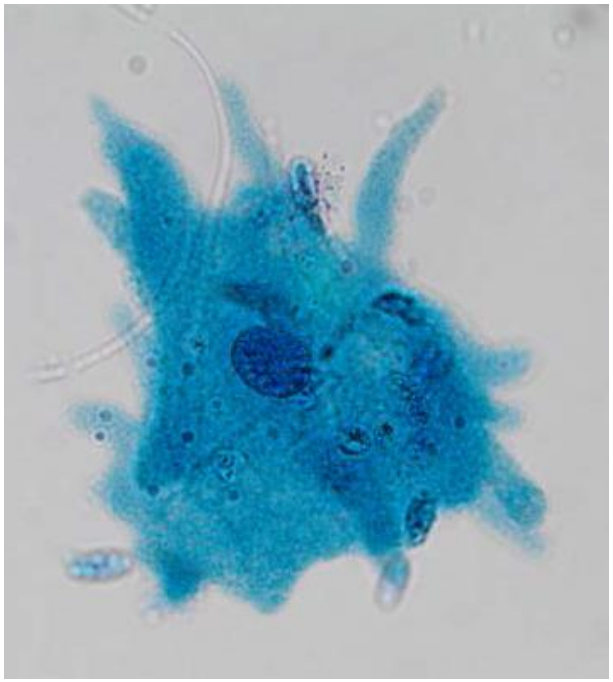
Protozoa



- **Rhizopoda - Amöben**

- **Die meisten Amöben leben im Süßwasser oder im Meer und ernähren sich von Bakterien und Algen.**

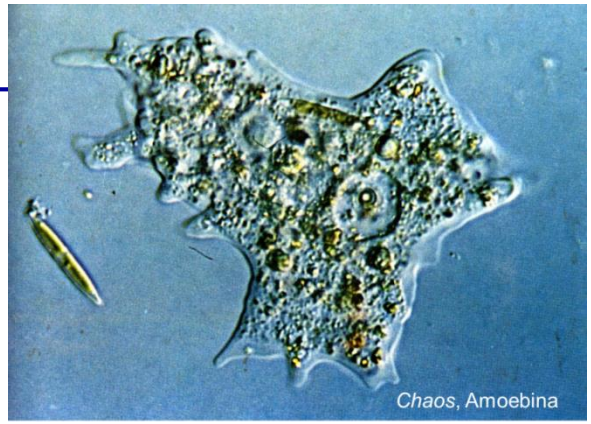
- **Einige Arten legen im Darm von verschiedenen Tieren, einige von ihnen sind pathogen**
  - **z.B. *Entamoeba histolytica,* Erreger der Amöben-Ruhr**

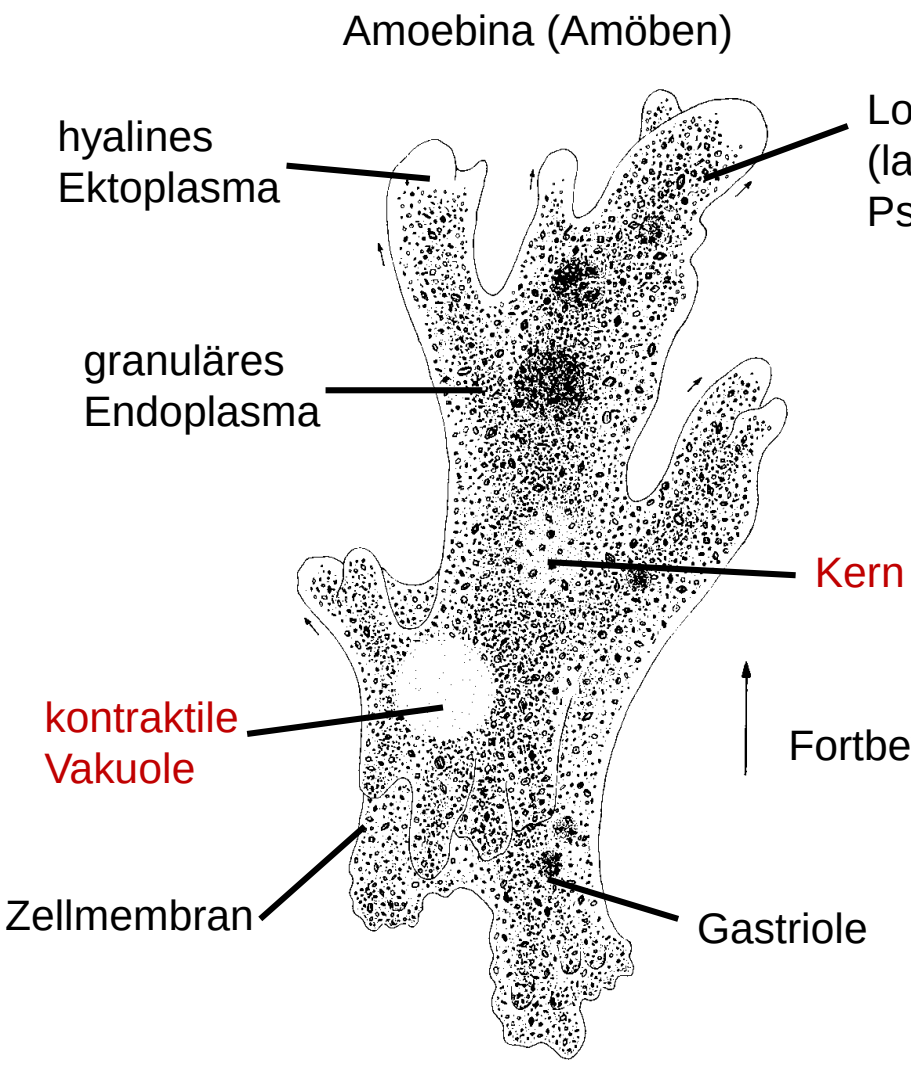


Amoeba proteus
- lebt in Tümpeln

Protozoa

- **Rhizopoda - Amöben**





Charakteristisches Merkmal:

- **Pseudopodien („Scheinfüßchen“), die durch Cytoplasmafluß bewegt werden**

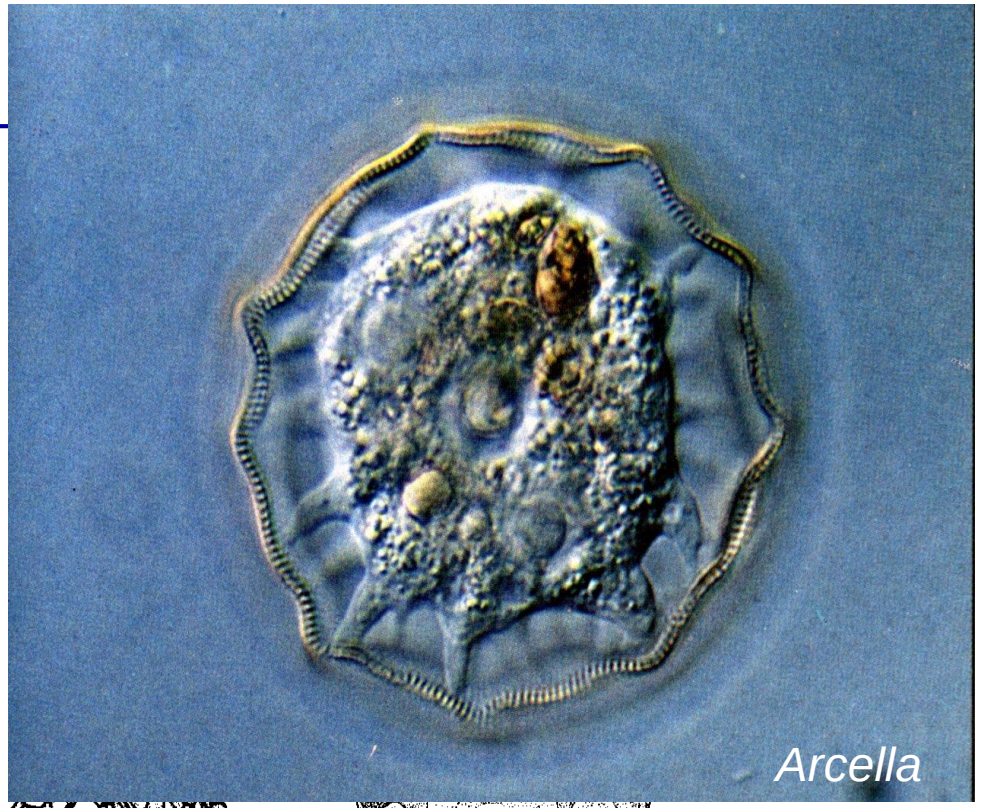
Nur asexuelle (ungeschlechtliche) Vermehrung:

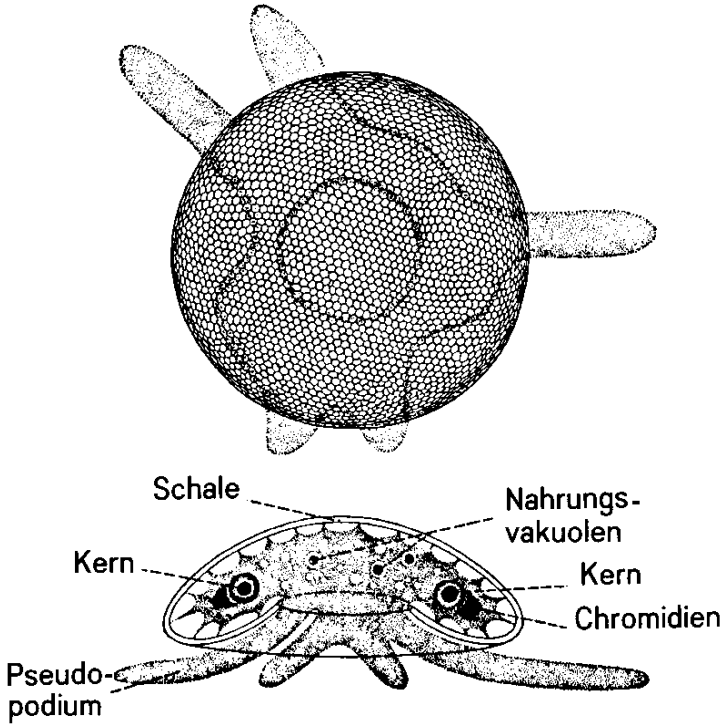
- Der Kernteilung folgt eine Zellteilung
- geschlechtliche Vermehrung ist bei Amöben nicht bekannt

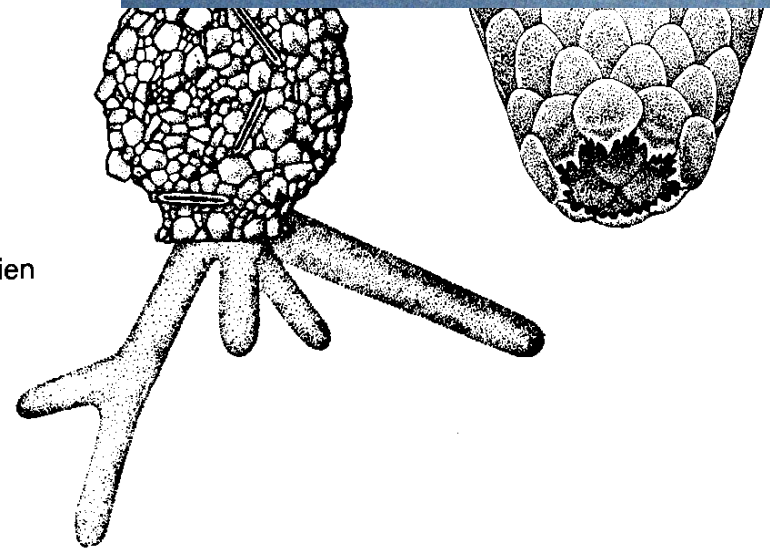
Protozoa

Rhizopoda

- **Testacea (Thekamöben)**



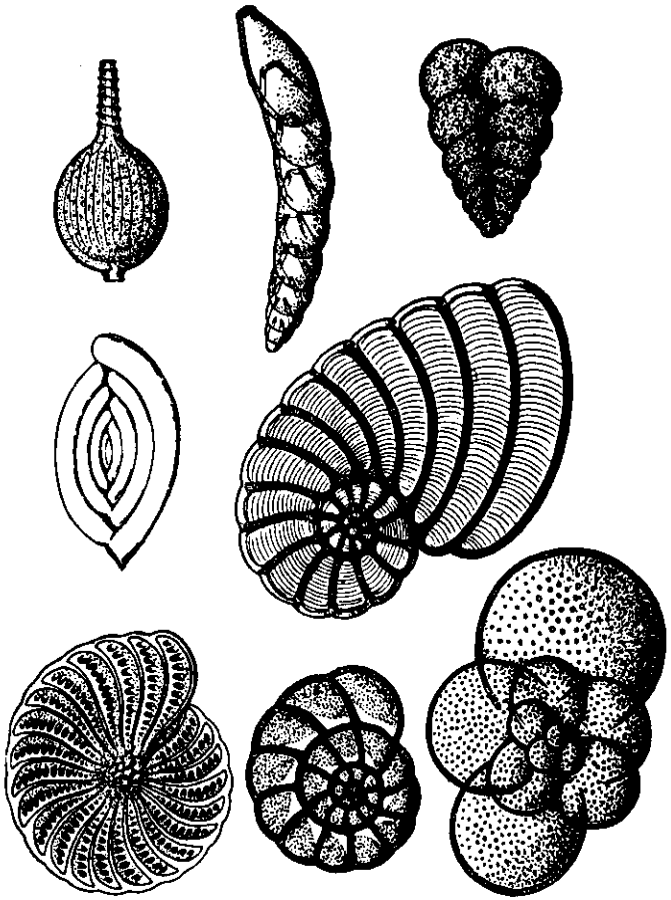




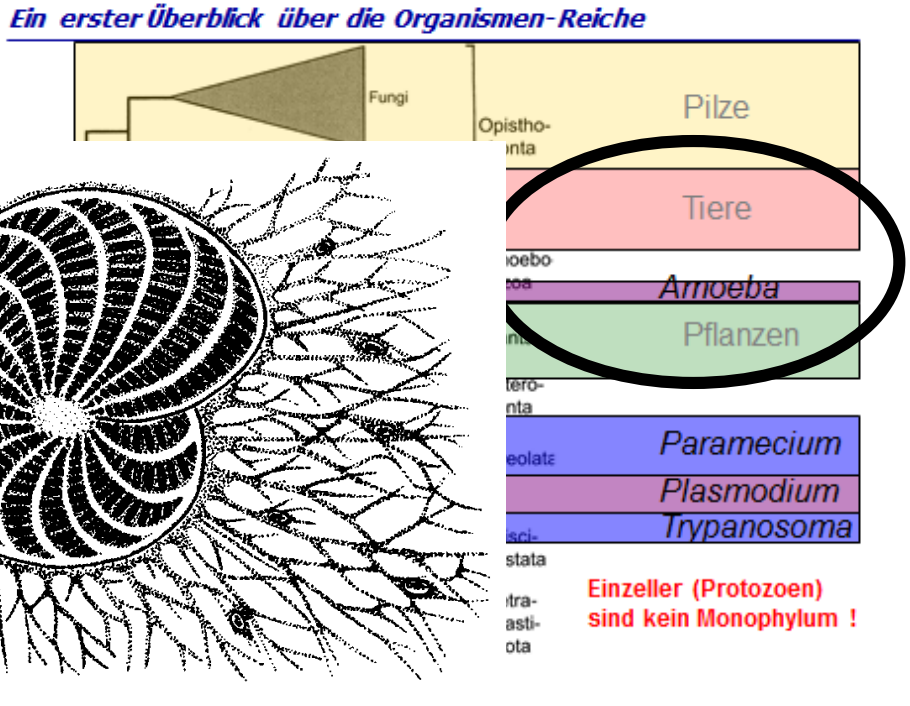
Protozoa

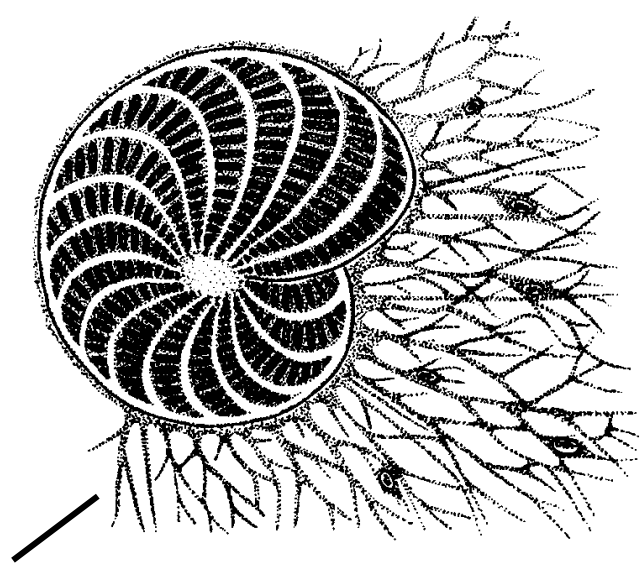
Rhizopoda

- **Foraminifera**



einkammerige (monothalame) oder
mehrkammerige (polythalame) Kalkskelette





Rhizopodien (Reticulopodien)

Protozoa

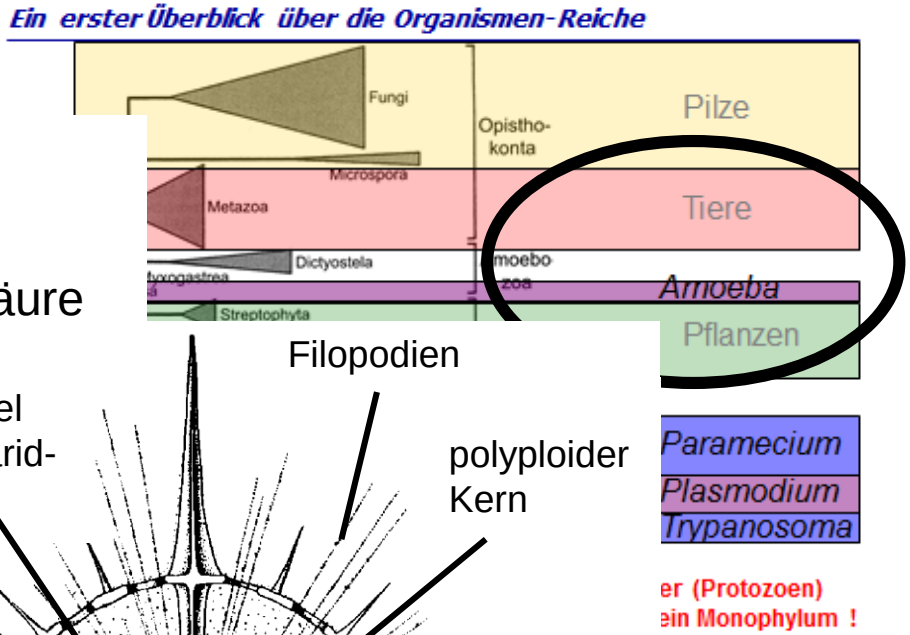
- **Foraminifera : im Meer so häufig, dass die abgesunkenen Gehäuse wichtiger Bestandteil des entstehenden Sediments sind**

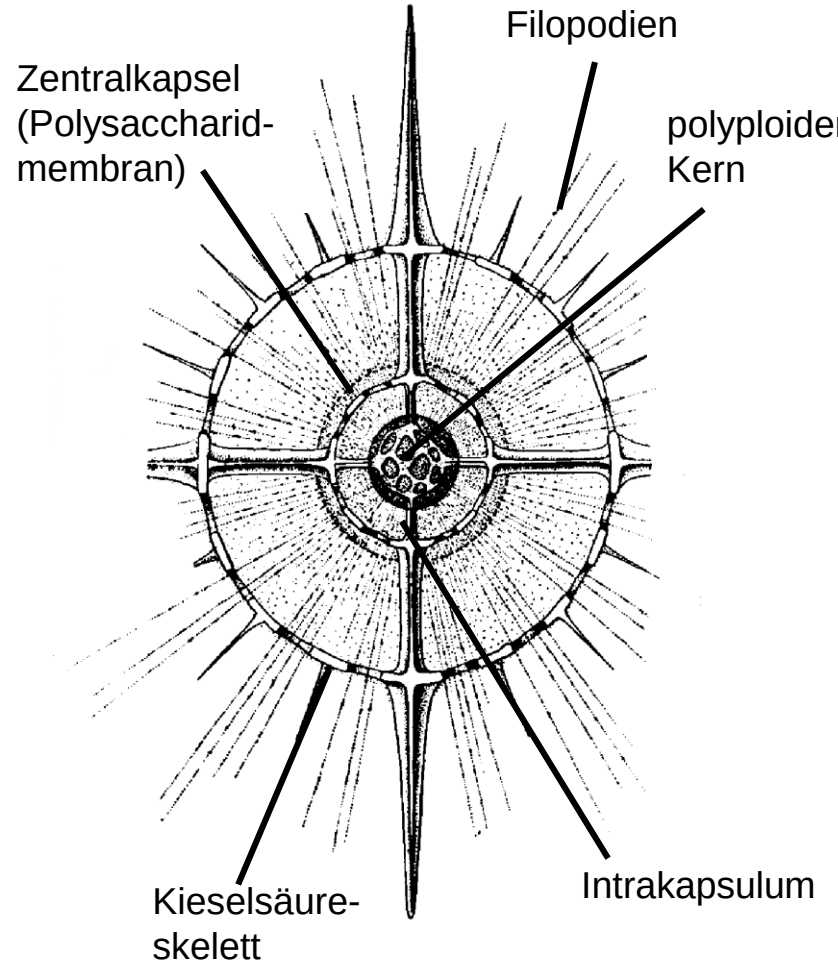
Nummulites gizehensis

Nummuliten im eozänen Kalkstein :
Die "wahren Baumeister" - Pyramiden von Gizeh

Protozoa

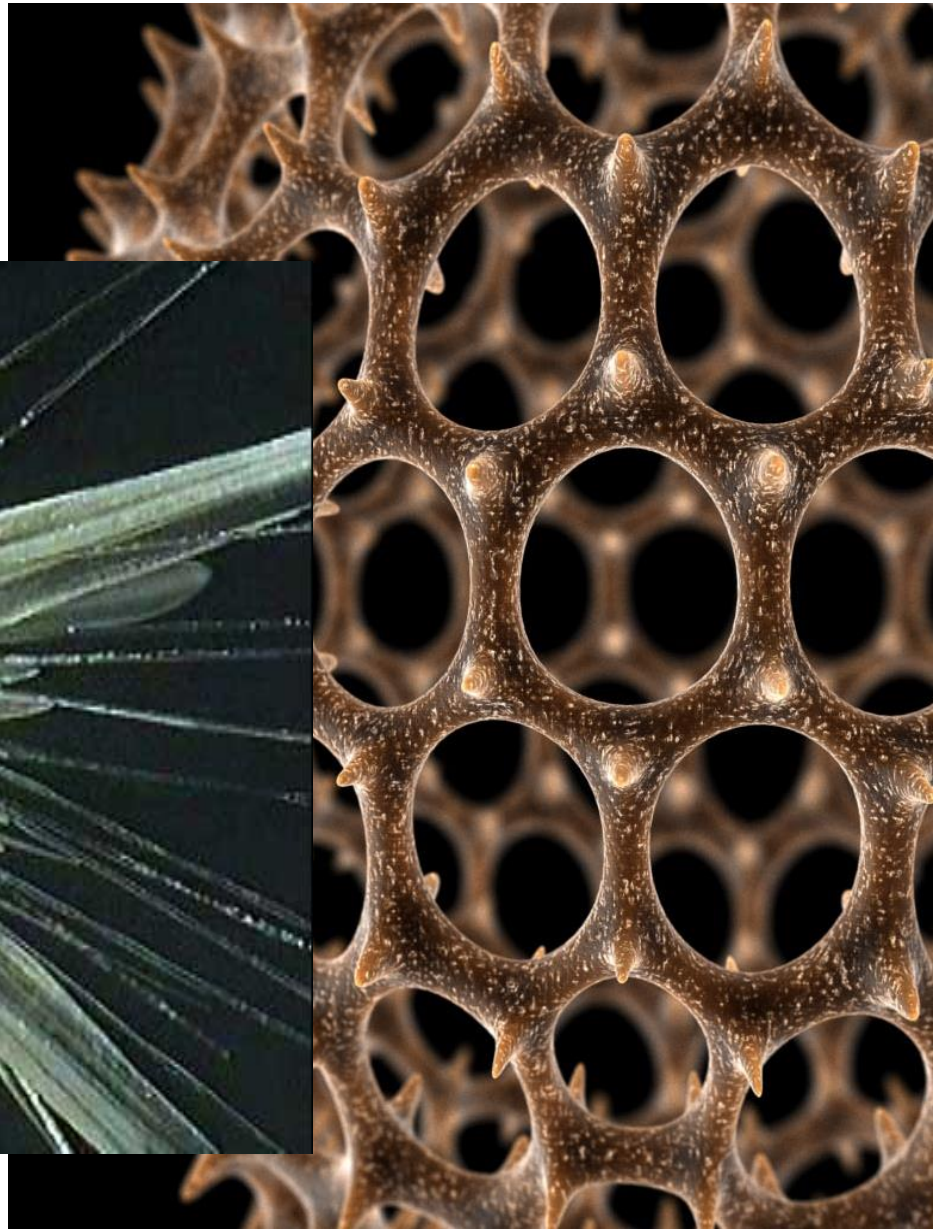
- **Radiolaria – marine Rhizopoda**
  mit einem hoch organisierten, symmetrischen Gehäuse aus Kieselsäure

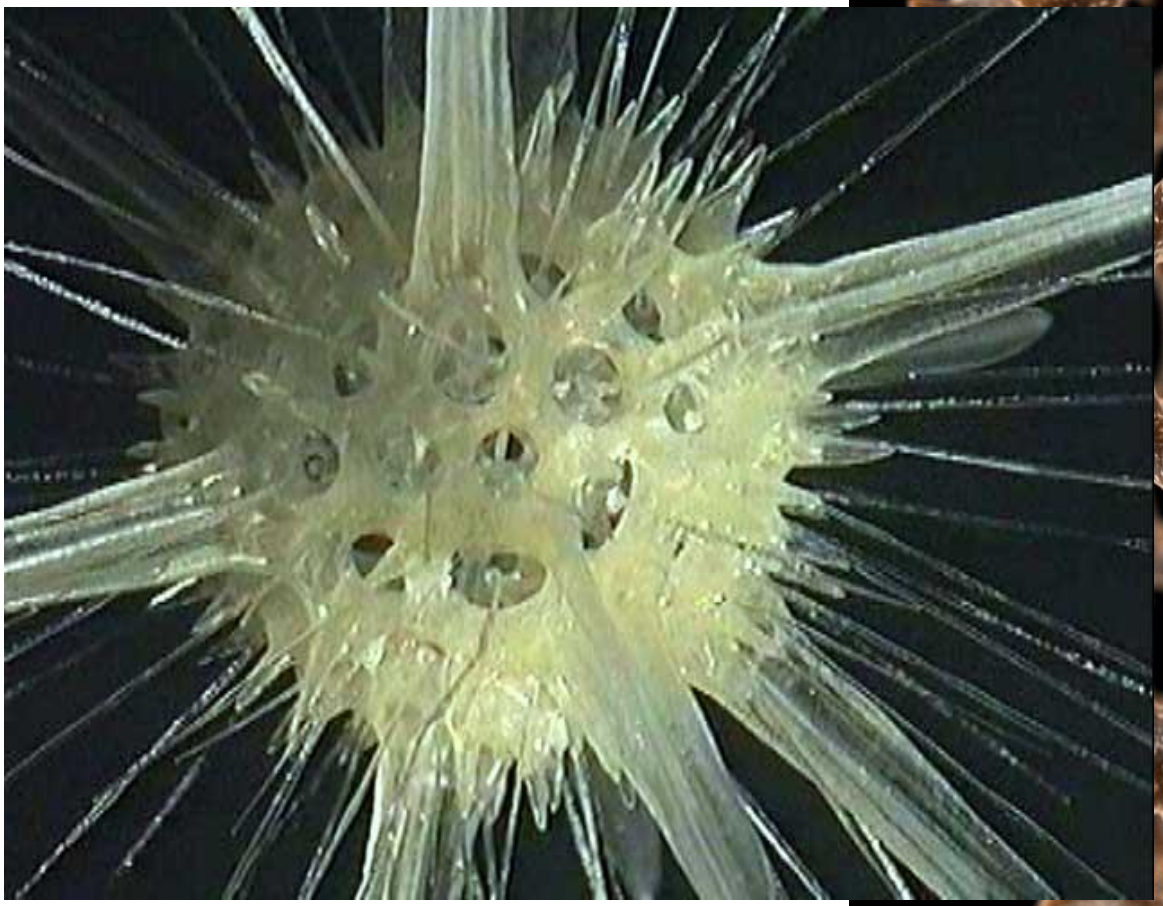




Protozoa

- **Radiolaria – marine Rhizopoda**
  mit einem hoch organisierten, symmetrischen Gehäuse
  aus Kieselsäure

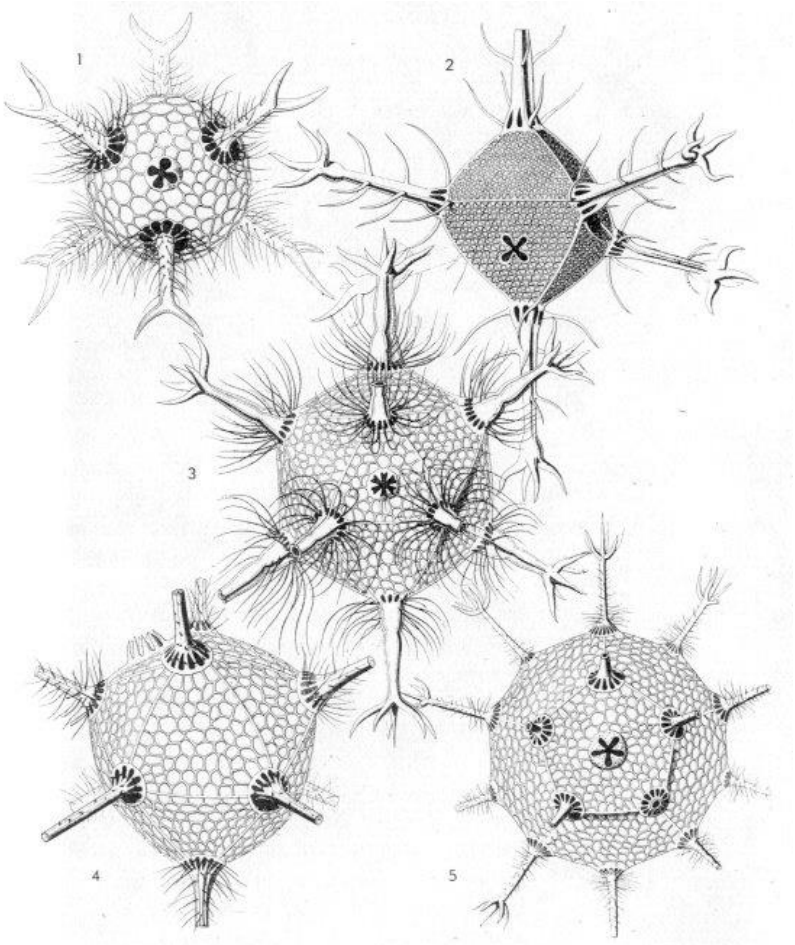


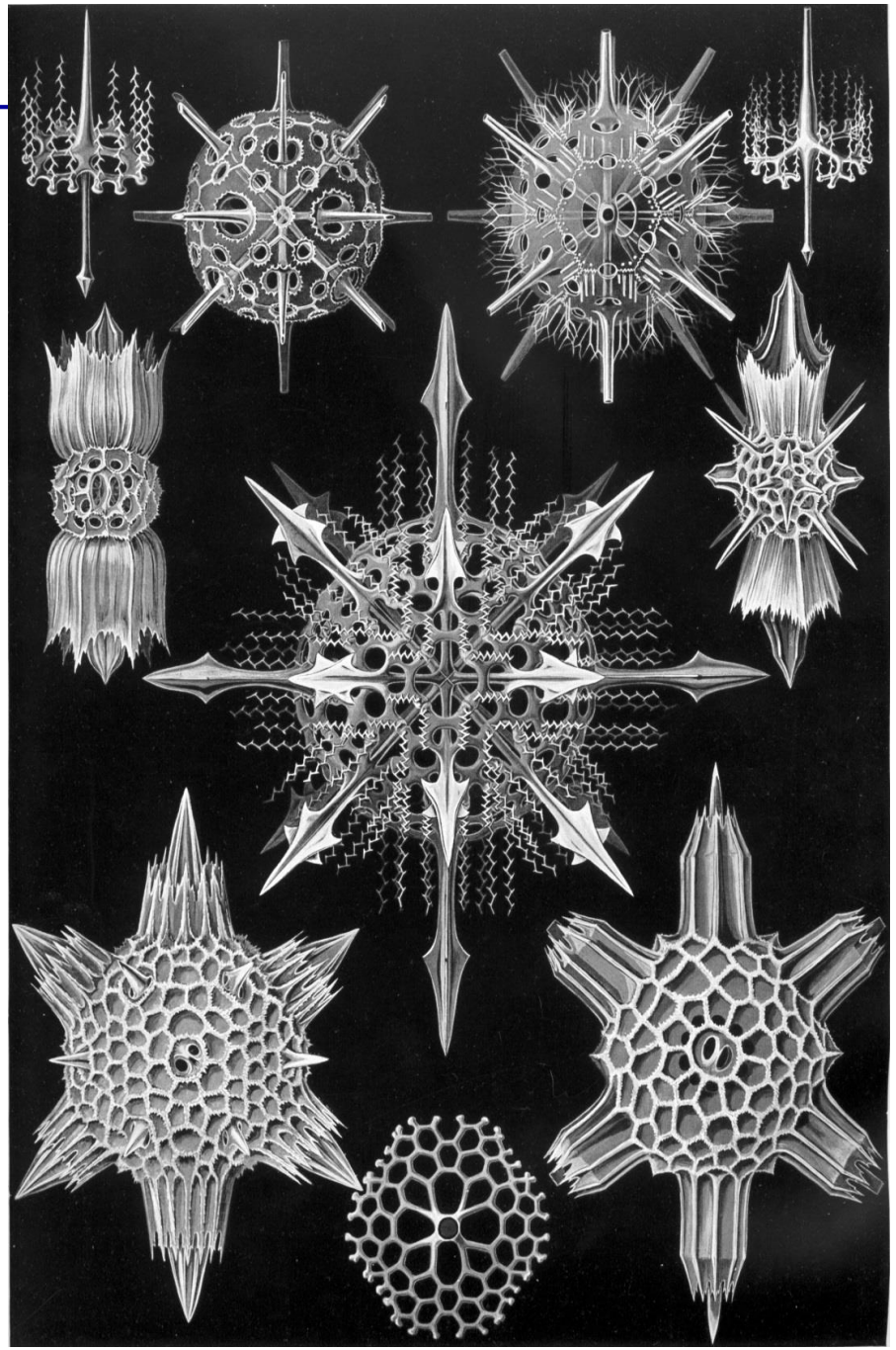


Protozoa

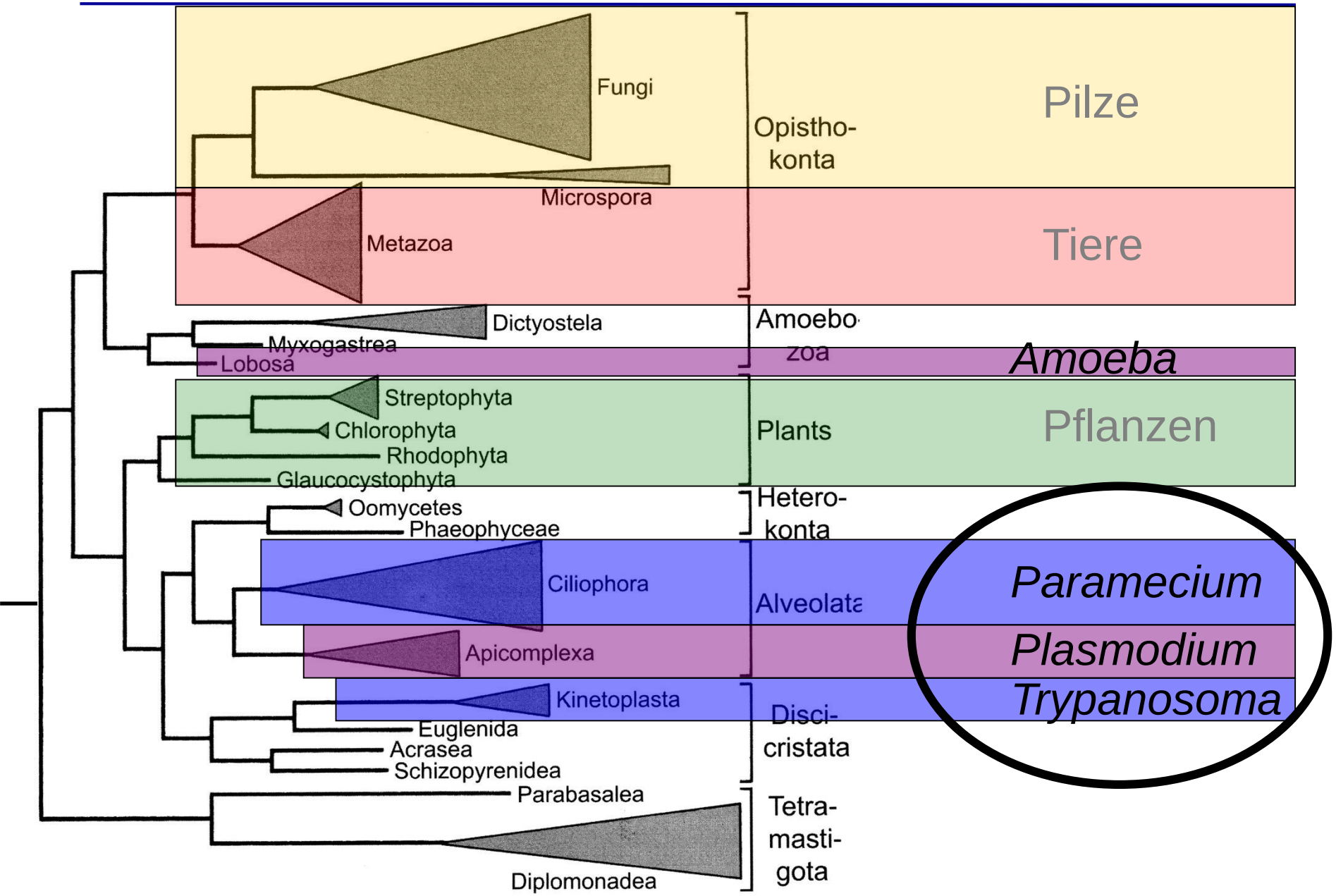
- **Radiolaria – marine Rhizopoda**

  bekannt durch Ernst Haeckels Buch *„Kunstformen der Natur“* (1899-1904)





Ein erster Überblick über die Organismen-Reiche



Protista

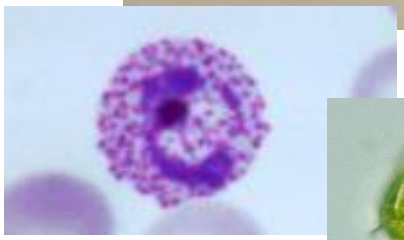
- **Alveolata -** flache Vakuolen unter der Zellmembran

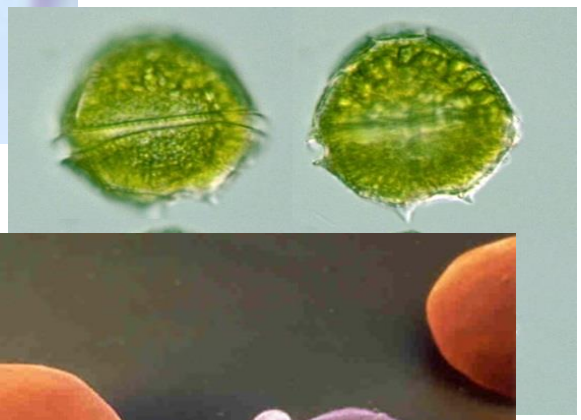
1. – Ciliata (Ciliophora)

Paramecium

2. – Apicomplexa

Plasmodium





3. – Dinoflagellata (autotroph)

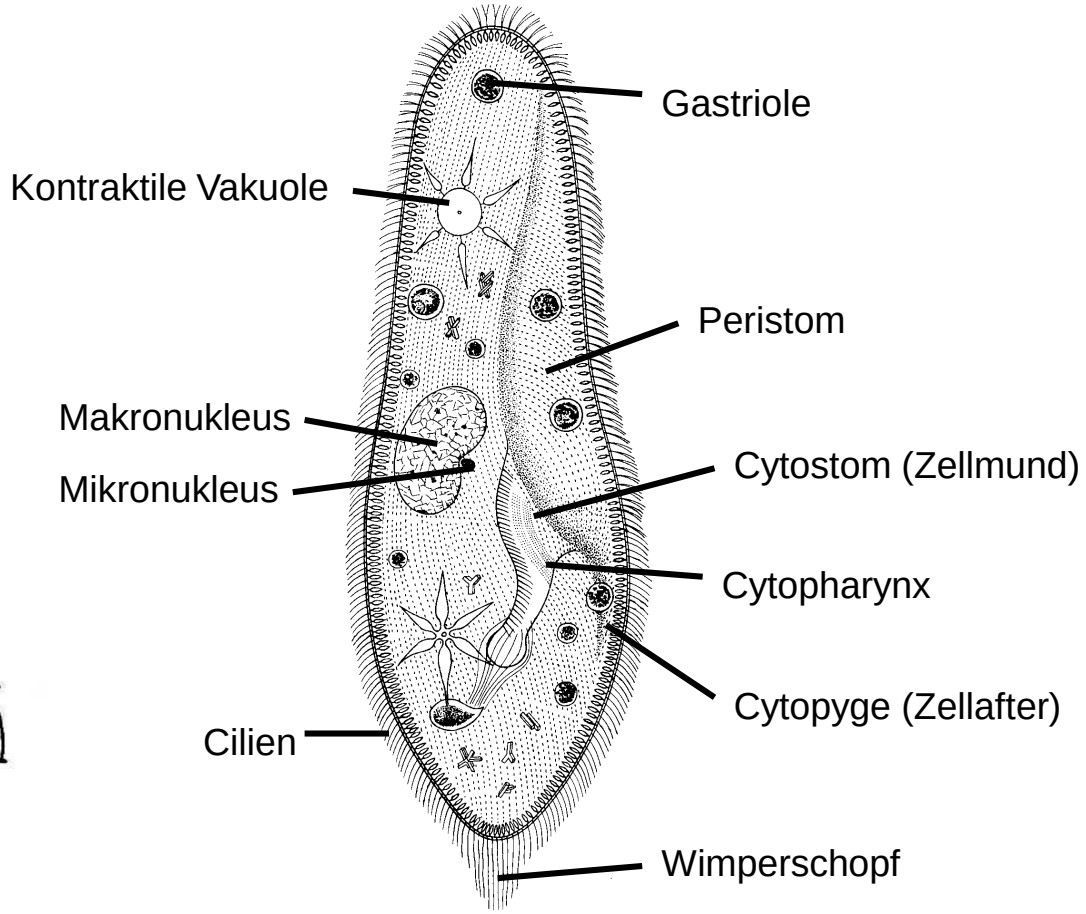
- **Kinetoplasta - *Trypanosoma***

Protista

- **Alveolata, Ciliophora (Ciliata)**

Ciliata
(Wimperntierchen)

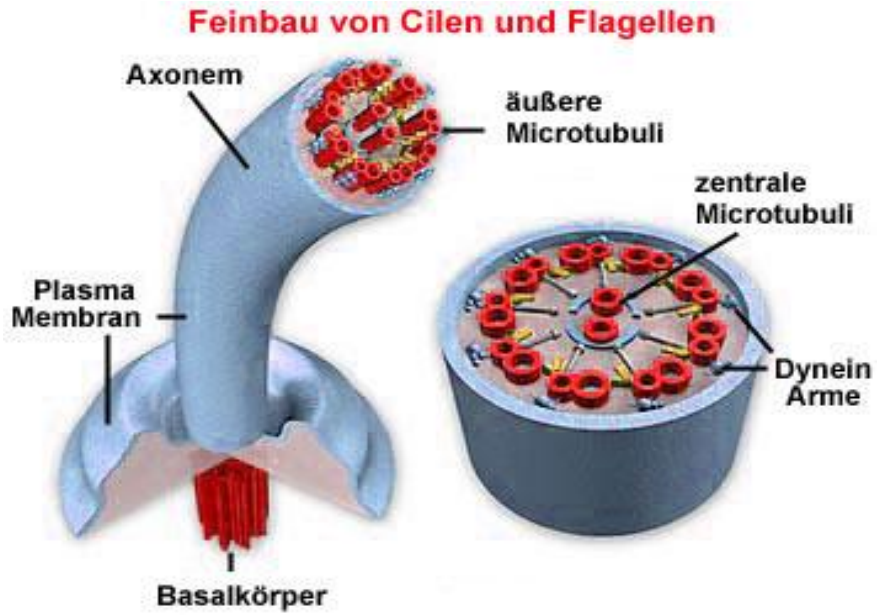
sind vollständig oder weitgehend mit Cilien bedeckt. Sie schlagen synchronisiert und dienen der Fortbewegung.



Paramecium

Protista

- **einige Einzeller und Tiere haben eine charakteristische Zellorganelle: Cilien**



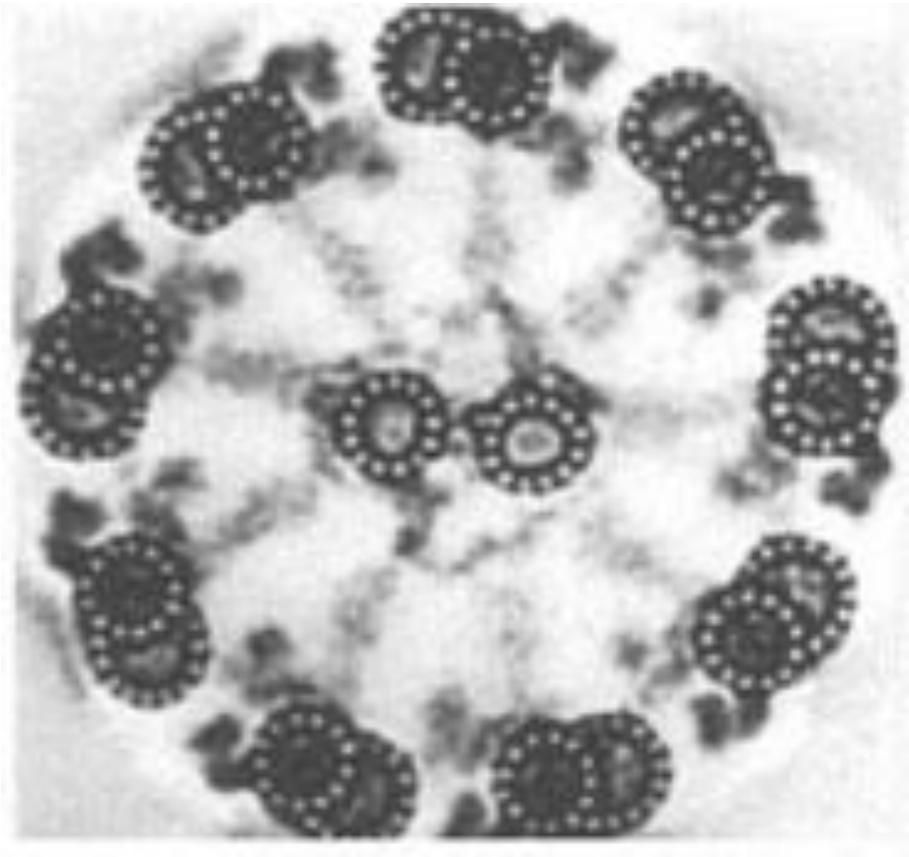
- **Cilien bestehen aus Mikrotubuli, die von der Zellmembran umgeben werden.**
- **Baustein der Mikrotubuli ist Tubulin.**
- **Durch Erweiterung/Verkürzung (Polymerisation/Depolymerisation) der Mikrotubuli sind die Cilien beweglich.**

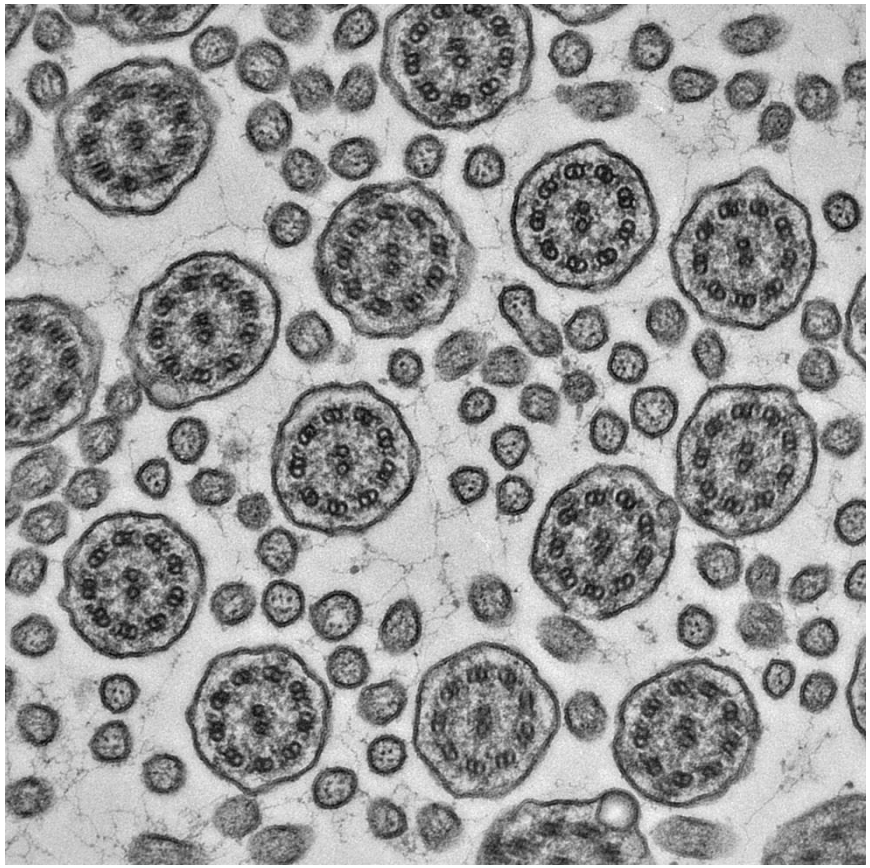
Protista

- **In einem Cilium sind Mikrotubuli in einem charakteristischen Muster angeordnet:**

  9 periphere Doppelmikrotubuli +
  2 zentrale Einzelmikrotubuli

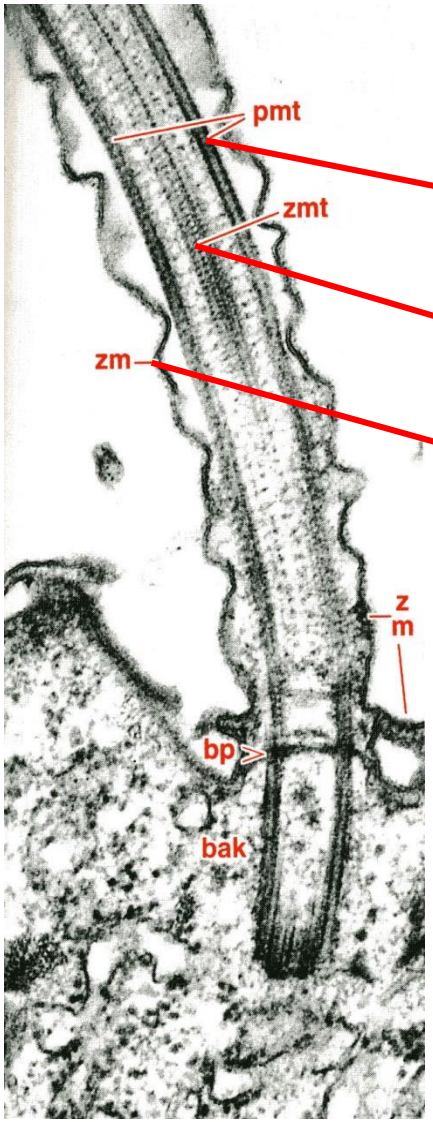
- **Formel: 9 x 2 + 2**

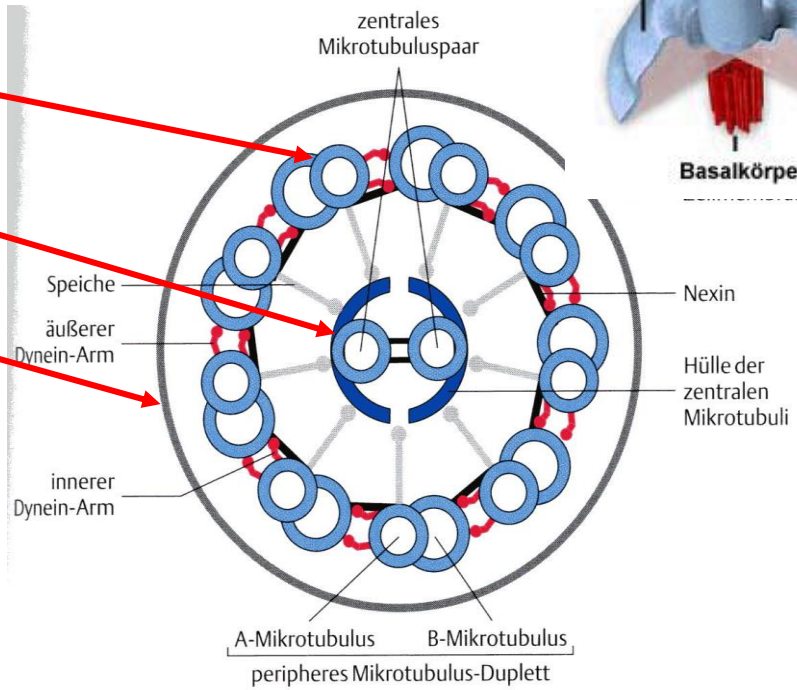


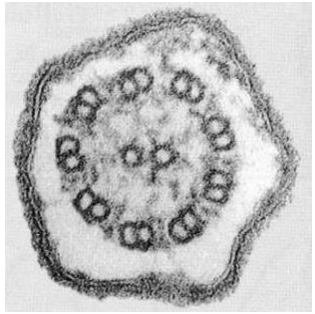


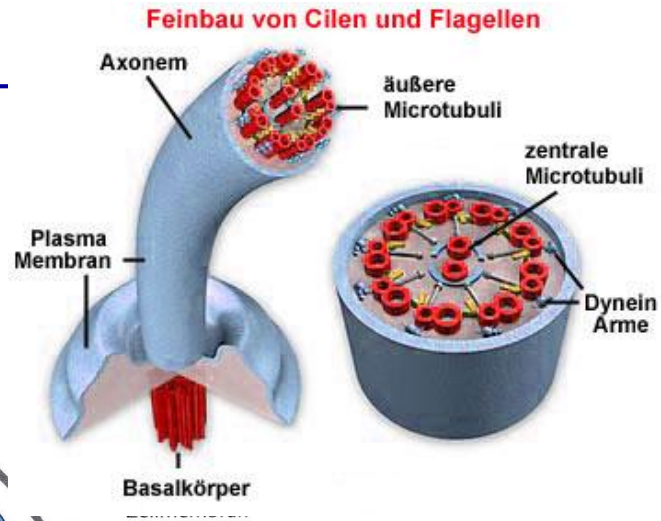
Protista

- **Geißeln und Cilien - Ultrastruktur**

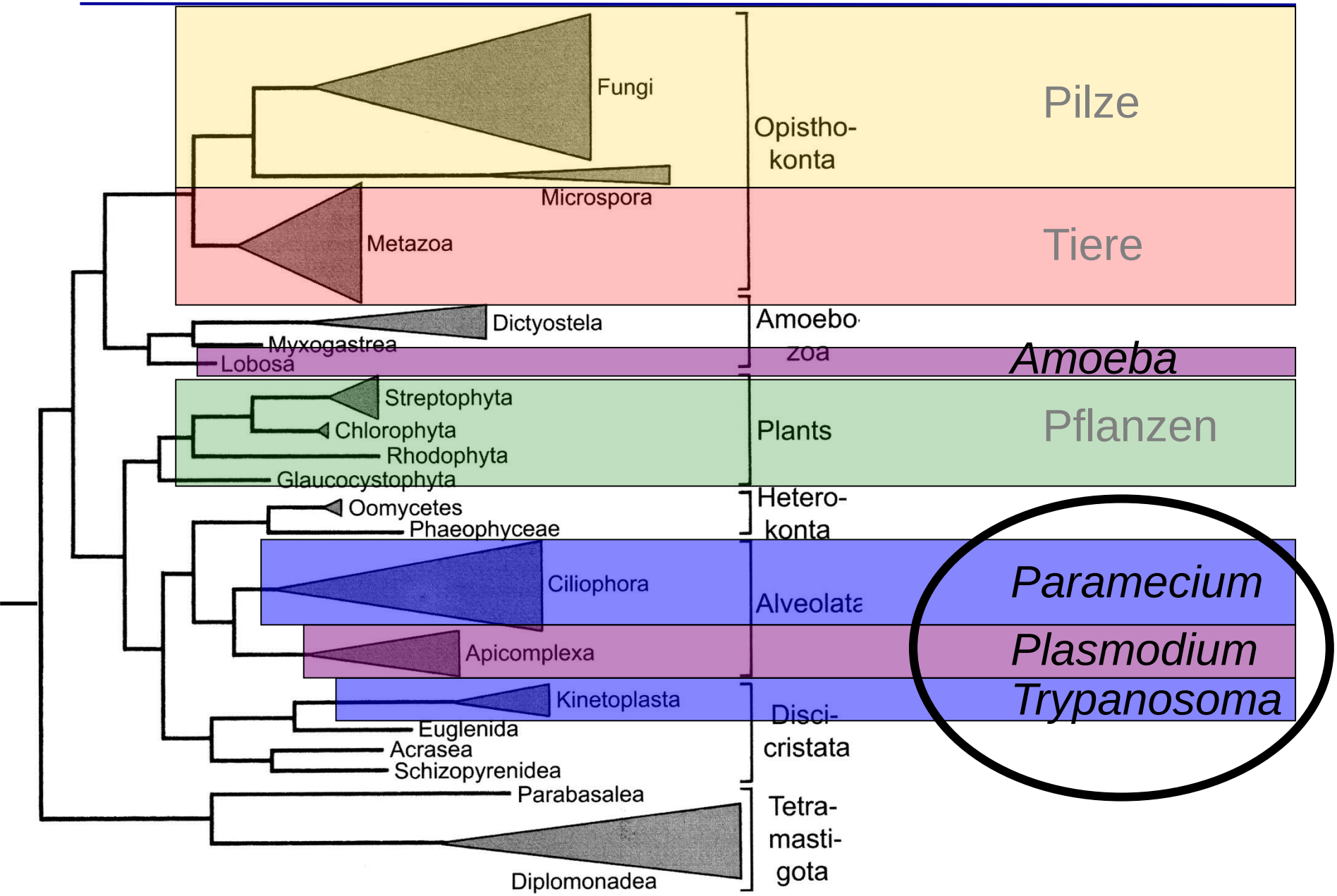








Ein erster Überblick über die Organismen-Reiche



Protista

- **Blutausstrich mit *Plasmodium falciparum***

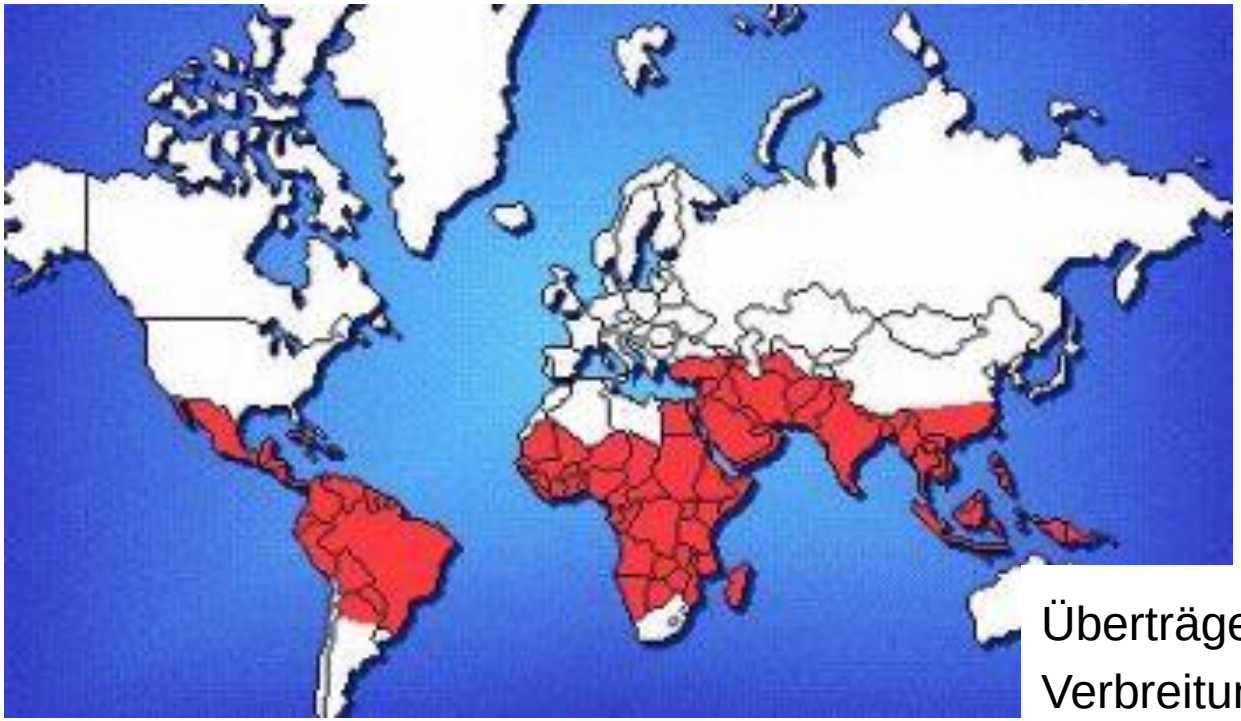
Protista

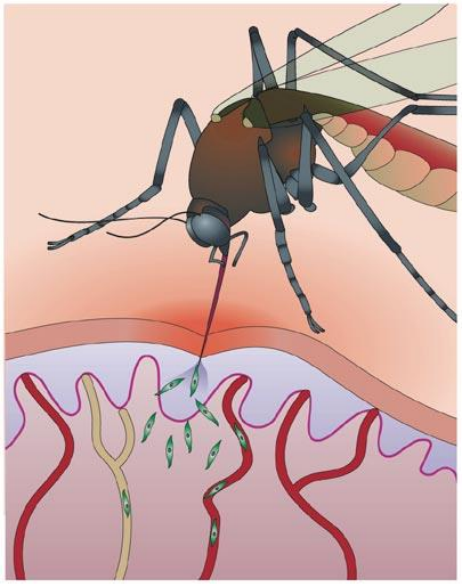
- **Apicomplexa, *Plasmodium***

Vier Arten - *Plasmodium vivax*, *ovale*, *falciparum* und *malariae* - sind Erreger der **Malaria**.

Pro Jahr gibt es 300-500 Mio. Neuerkrankungen, 1,5 - 2,7 Mio. Menschen sterben jährlich

Plasmodium-Sporozoit



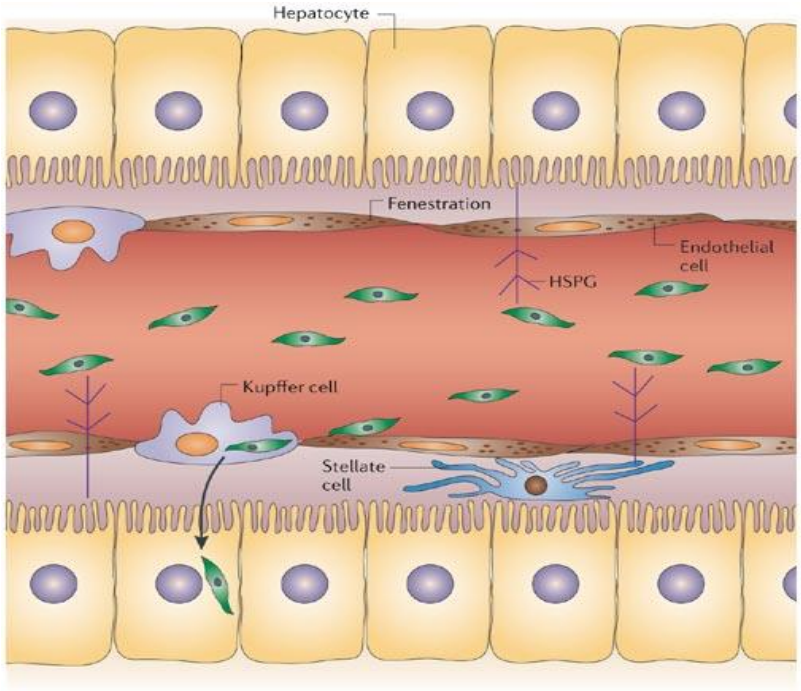


Überträger: ***Anopheles*-Mücke**

Verbreitung: Tropen

Protista

- **Apicomplexa, *Plasmodium***

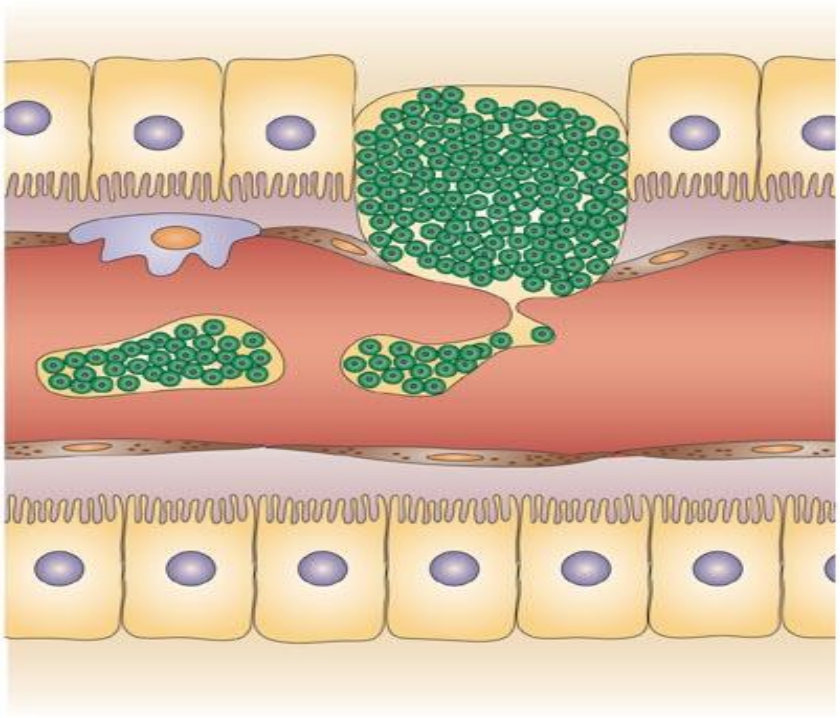


1. Sporozoiten

- infizieren Leberzellen

Plasmodium-Sporozoit

2. vermehren sich ungeschlechtlich und massenhaft zu Merozoiten, dringen dann in Erythrocyten ein



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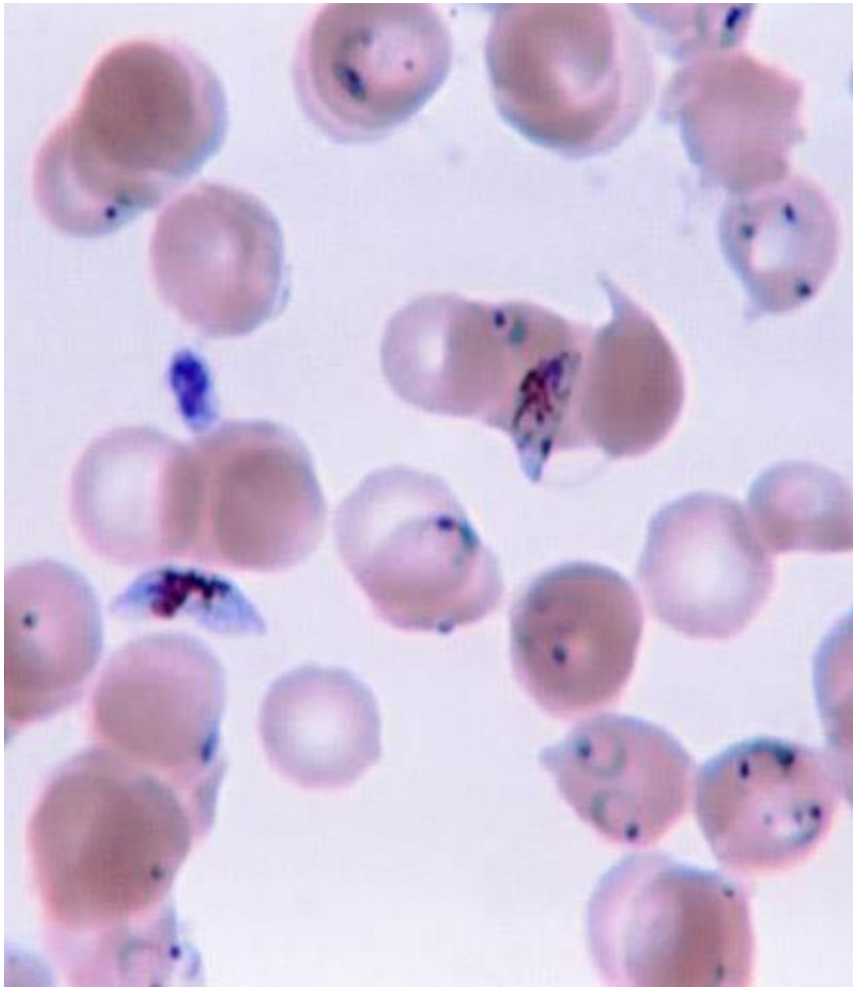
Protista

- **Apicomplexa, *Plasmodium***

- **In Erythrocyten findet ebenfalls eine ungeschlechtliche Vermehrung statt.**

- **Durch Platzen der Erythrocyten werden die Merozoiten frei, besiedeln neue Blutkörperchen**

- **Dieser Vorgang ist +/- synchronisiert resultiert in Fieberschüben**

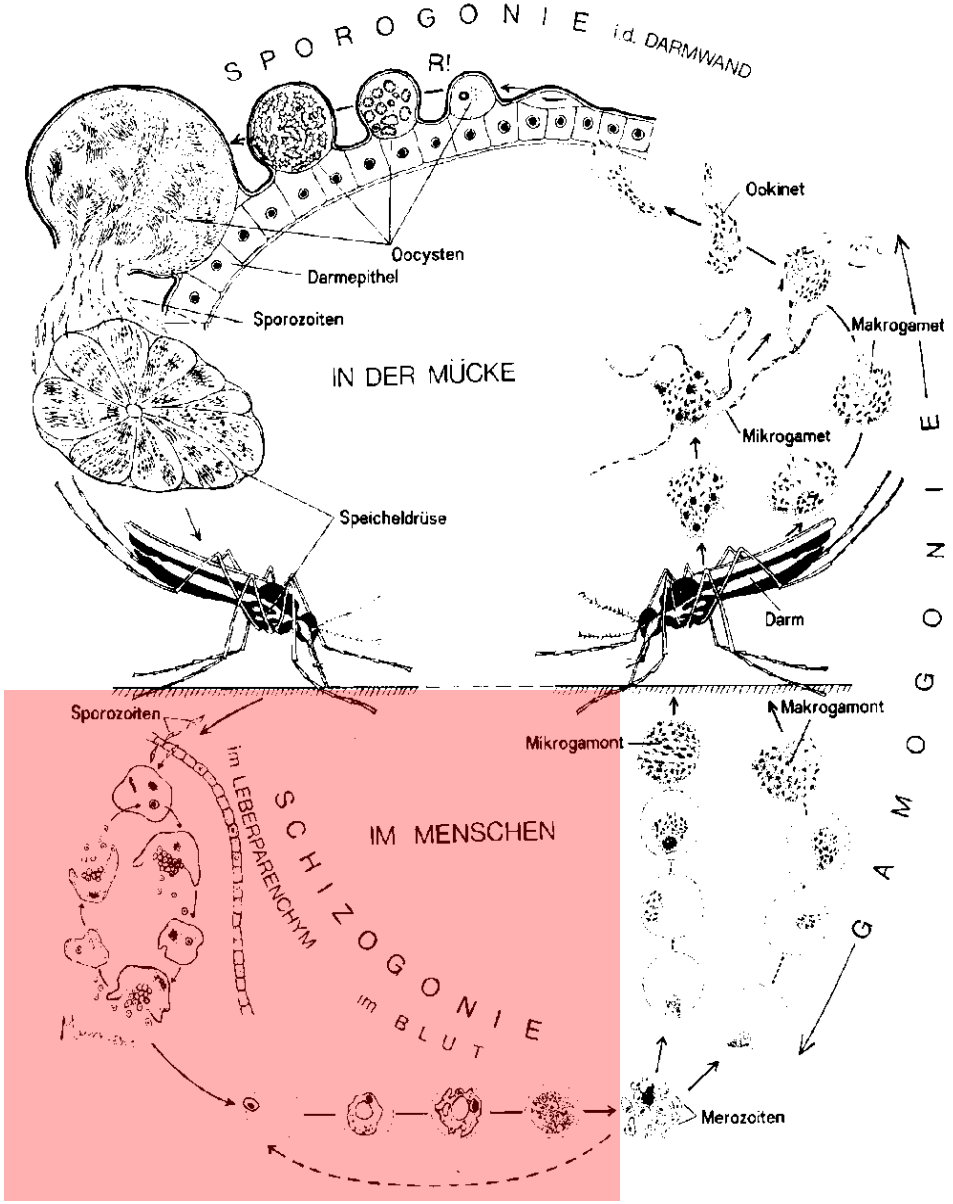


Der Malaria-Zyklus

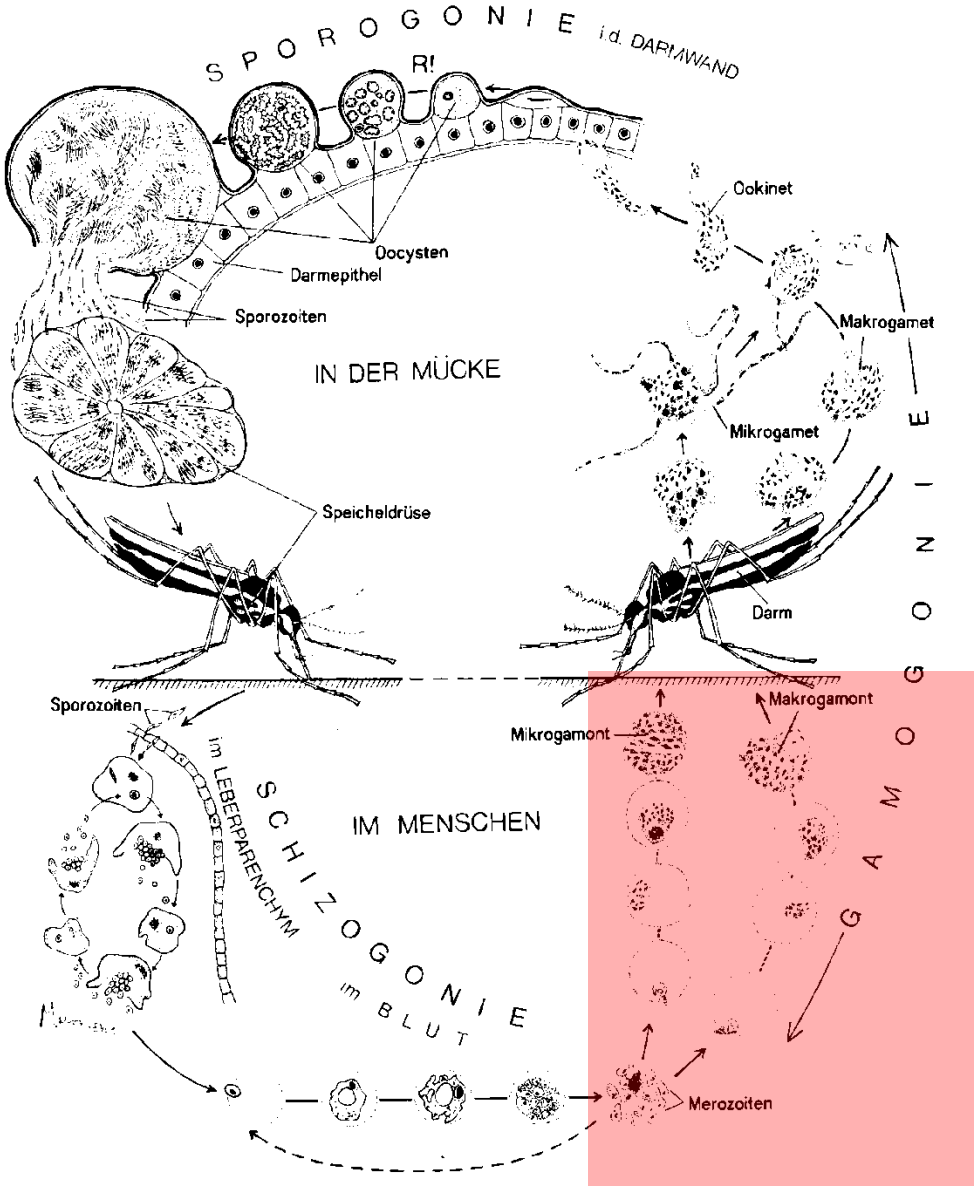
- **1. Schizogonie**

Wo? Im Menschen, in Leberzellen und im Blut

Beim Stich überträgt die Mücke Sporozoiten.
Diese gelangen über das Blut in Leberzellen.



Der Malaria-Zyklus

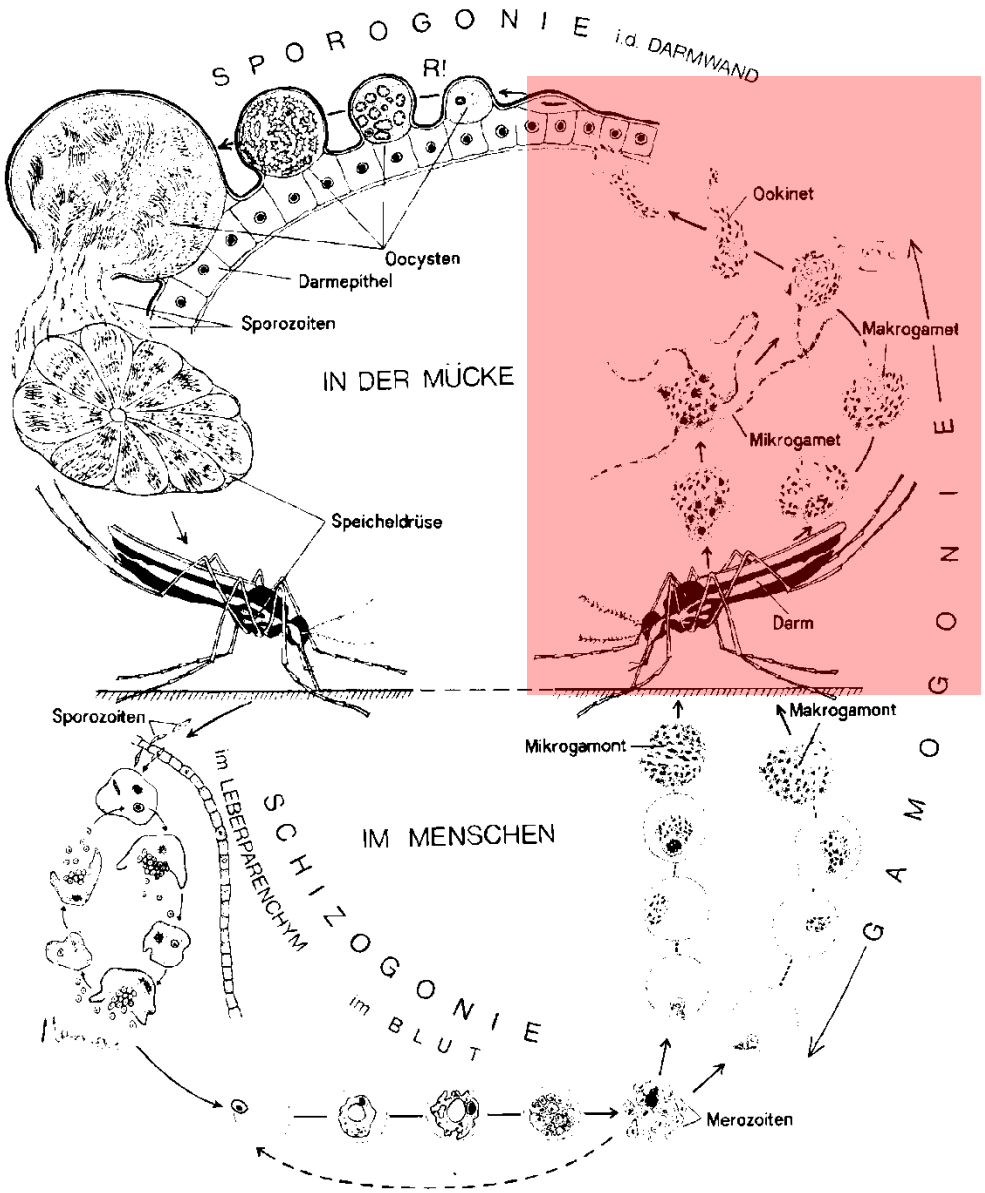


- **2. Gamogonie**

Wo? Im Menschen, im Blut

Ein Teil der Merozoiten entwickelt sich zu Mikro- und Makrogamonten.

Der Malaria-Zyklus

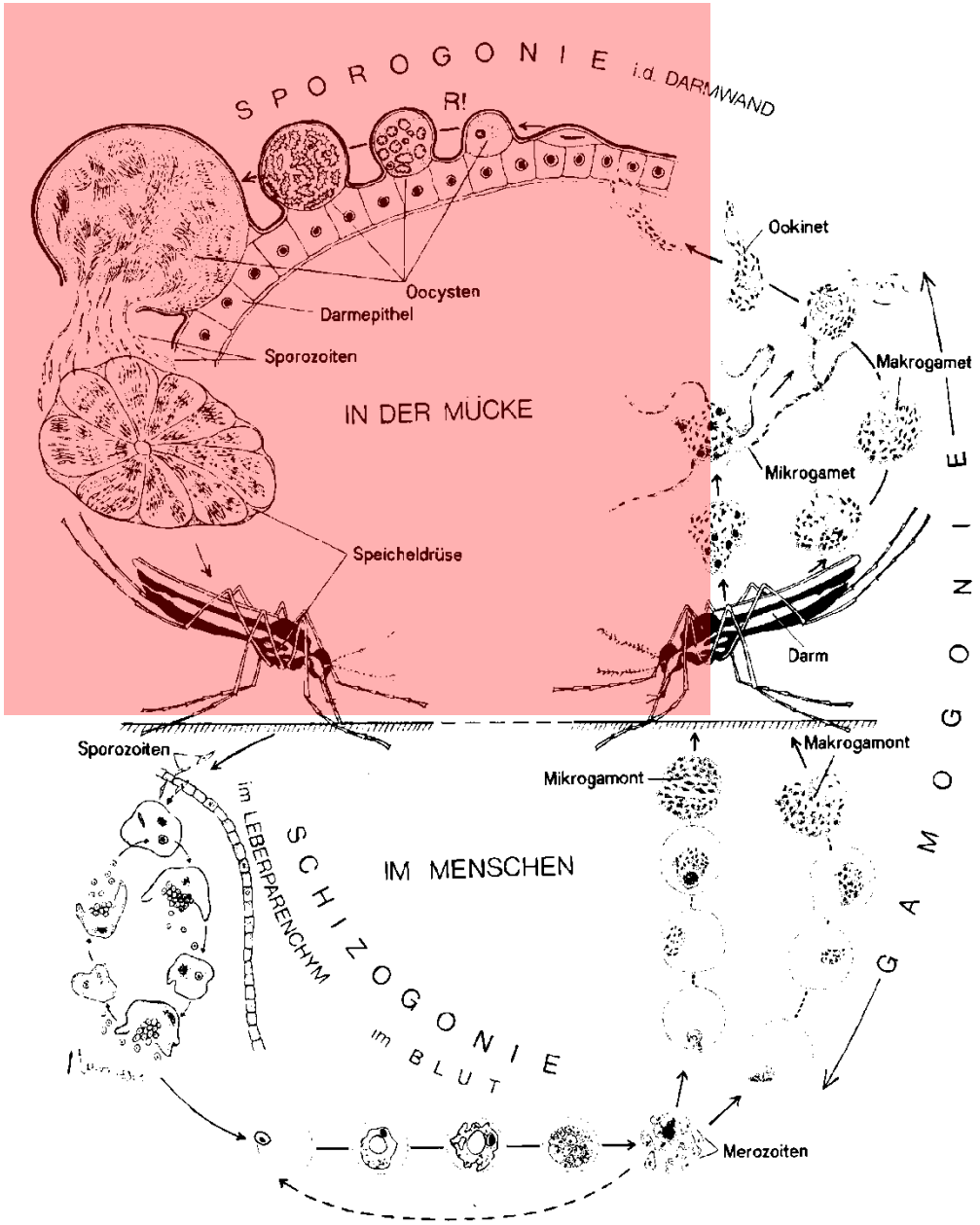


- **3. Gamogonie**

Wo? In der Mücke, im Darm

Mikro- und Makrogamonten entwickeln sich zu Mikro- und Makrogameten, die verschmelzen und die Zygote bilden.

Der Malaria-Zyklus

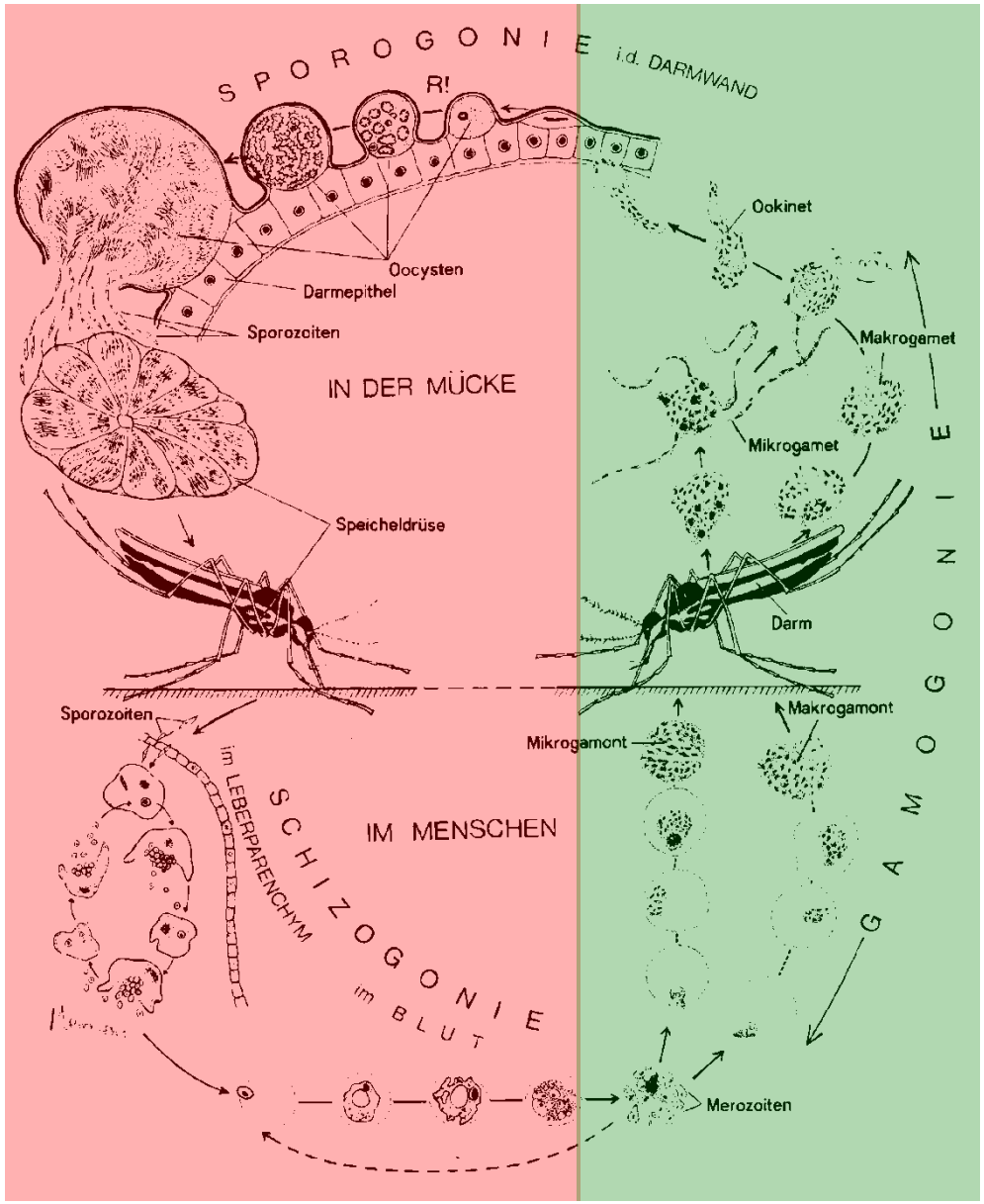


- **4. Sporogonie**

Wo? In der Mücke,
in Darmzellen

Die bewegliche Zygote befällt Darmzellen und bildet ungeschlechtlich viele Sporozoiten, die freiwerden und über die Leibeshöhle in die Speicheldrüsen gelangen.

Der Malaria-Zyklus



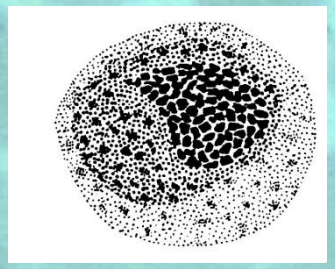
- **Zusammenfassung:**
- 2x ungeschlechtliche Fortpflanzung

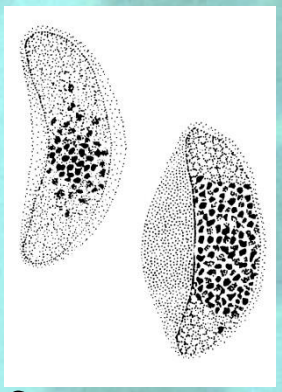
  Vermehrung der infektiösen Stadien
- 1x geschlechtliche Fortpflanzung

  Neukombination des Erbgutes

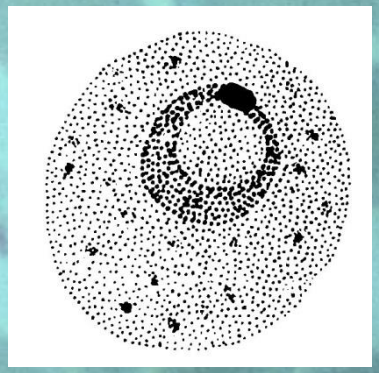
Blutausstrich mit *Plasmodium falciparum*

„Schizont“, kurz vor dem Entlassen der Merozoiten



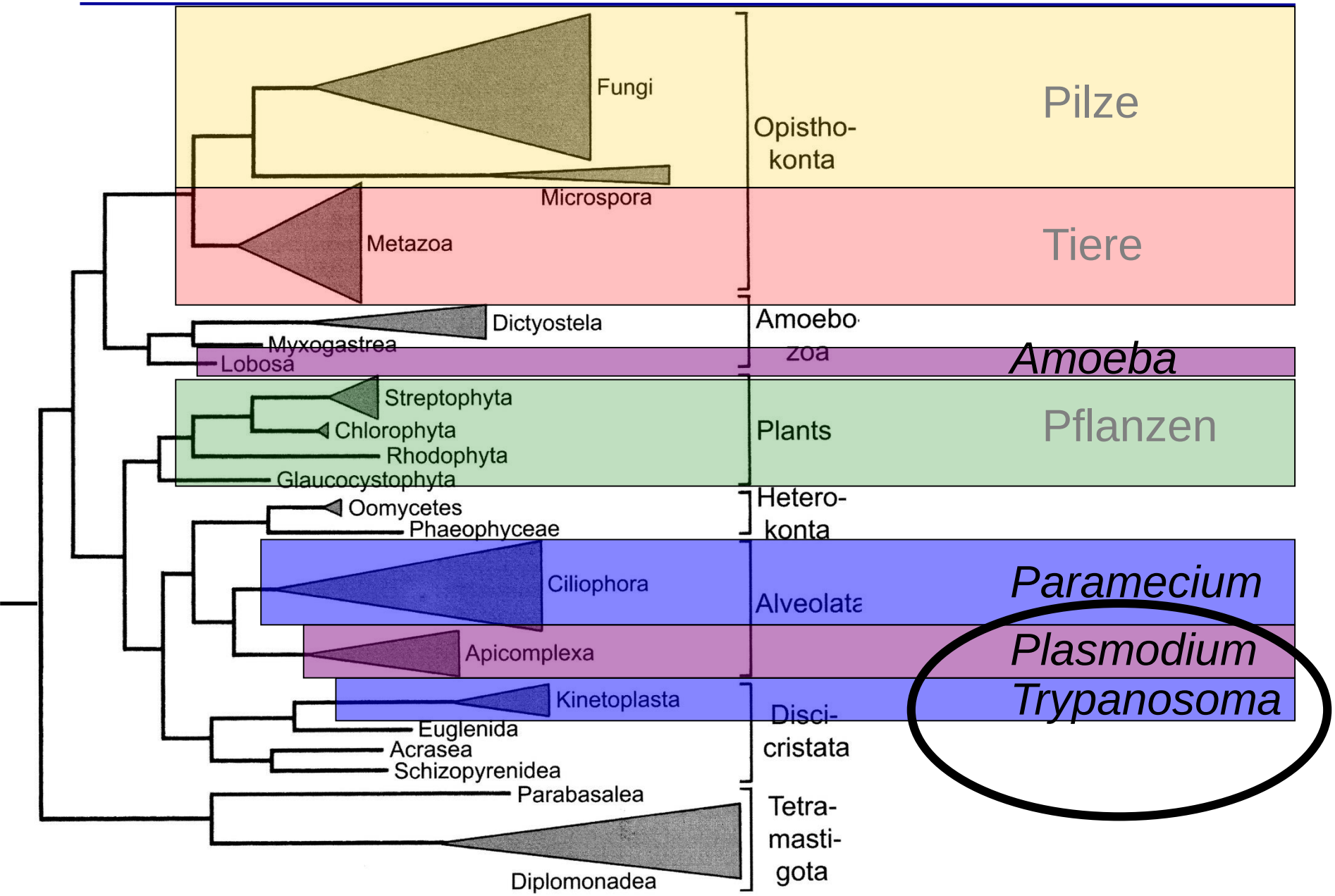


Gamont



„Siegelring-stadium“

Ein erster Überblick über die Organismen-Reiche



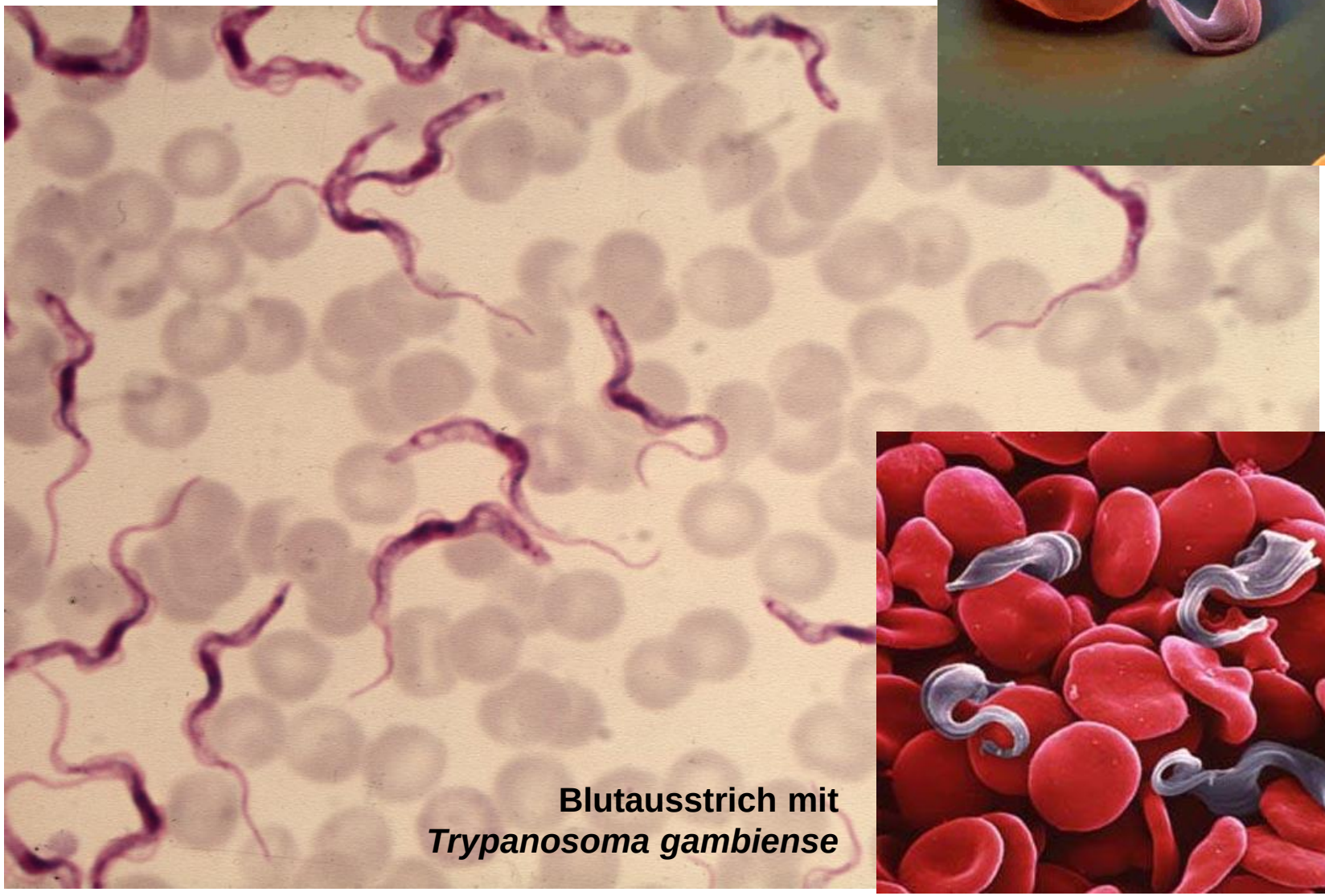
Protista

- **Kinetoplastida, *Trypanosoma***

Tsetse-Fliege (*Glossina*)

Protista

- **Kinetoplastida, *Trypanosoma***

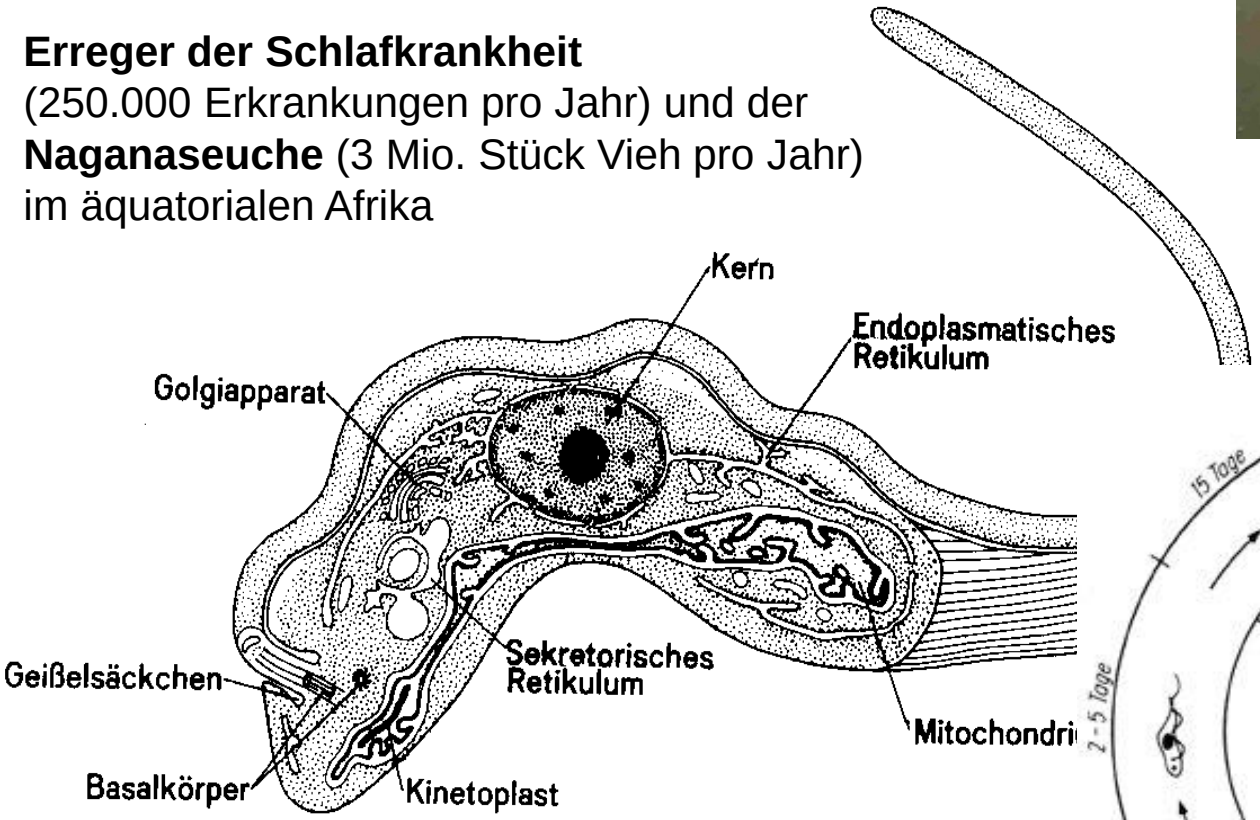


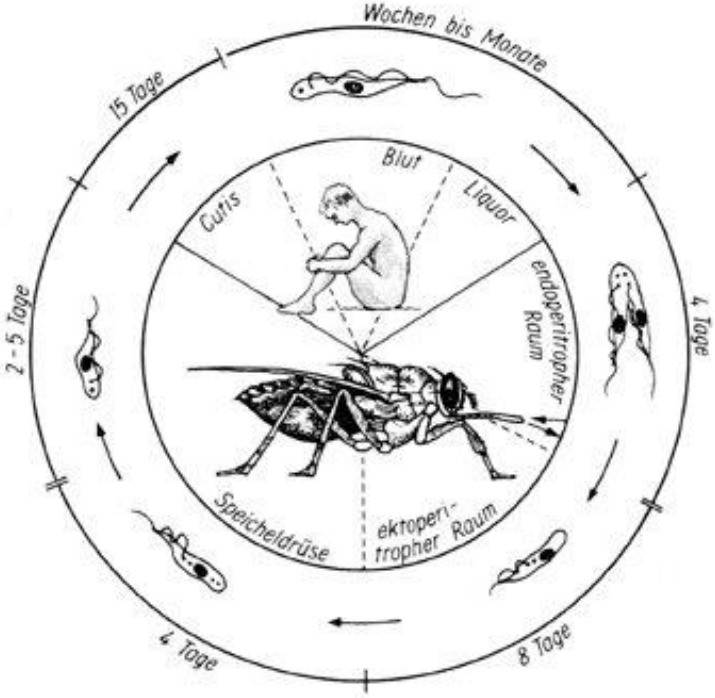
Blutausstrich mit
Trypanosoma gambiense

Protista

- **Kinetoplastida, *Trypanosoma***

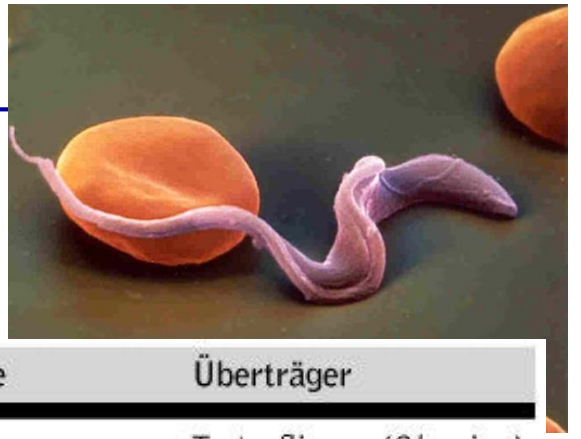
Erreger der Schlafkrankheit
(250.000 Erkrankungen pro Jahr) und der **Naganaseuche** (3 Mio. Stück Vieh pro Jahr) im äquatorialen Afrika





Protista

- **Kinetoplastida, *Trypanosoma***

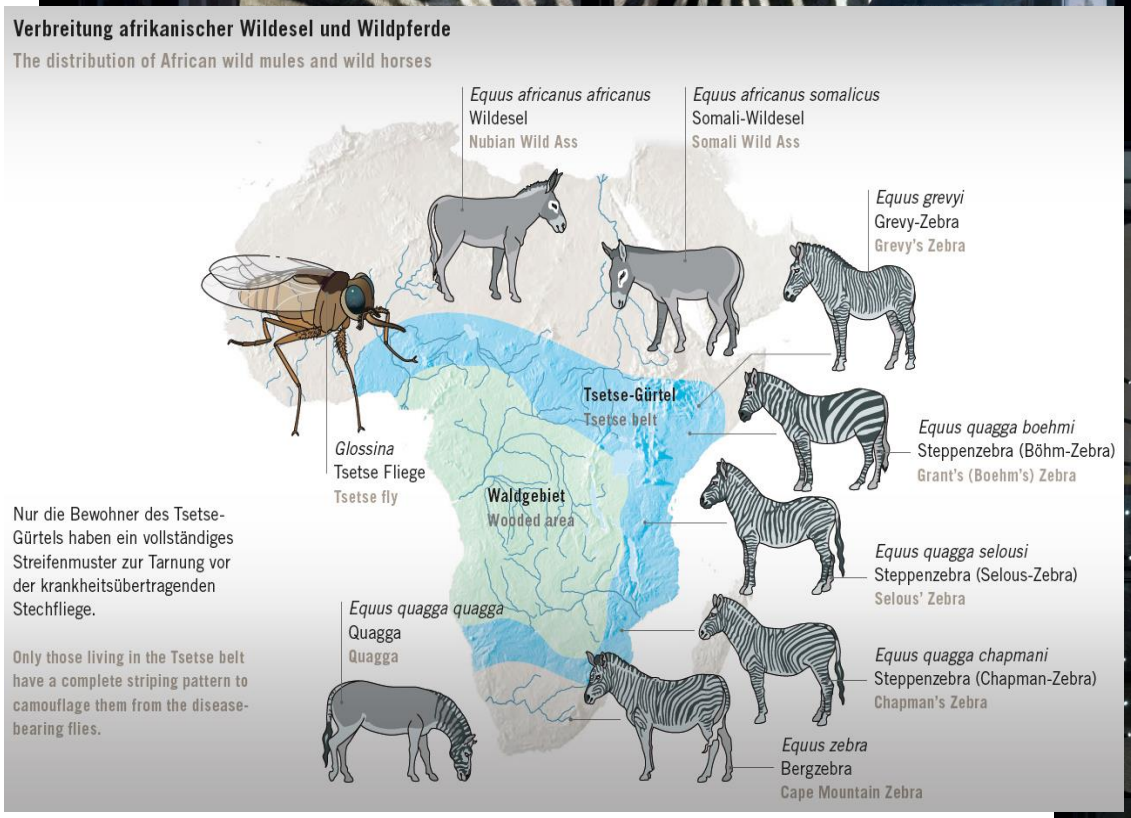


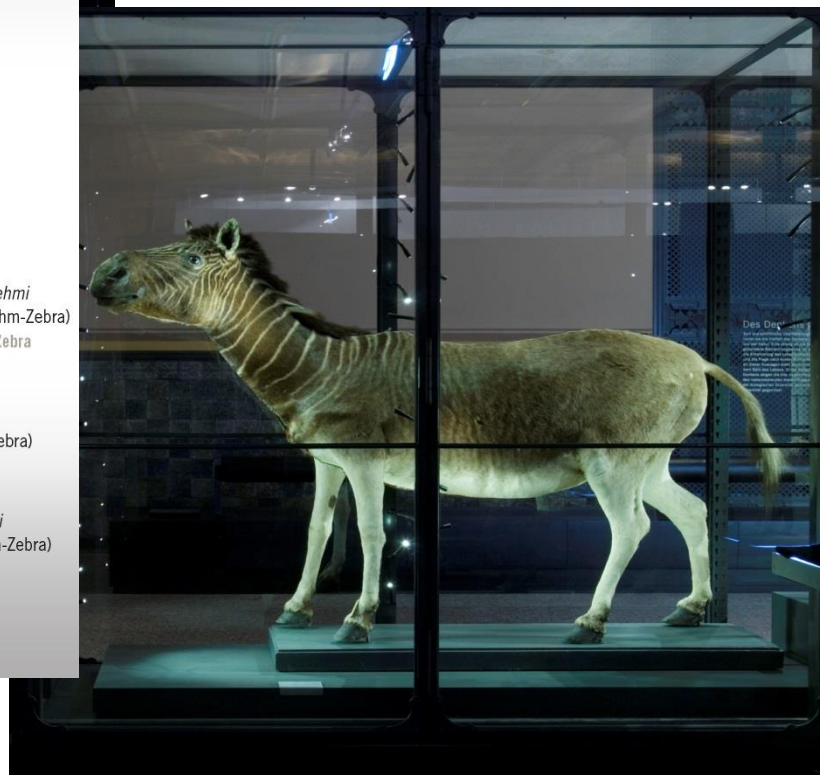
Art	Wirte	Verursachte Krankheit	Symptome	Überträger
T. brucei brucei	Pferde, Schweine, Nagetiere, Wiederkäuer	Nagana-Seuche	Fieber, Meningoencephalitis, Lähme	Tsetsefliegen *(Glossina)*
T. brucei gambiense	Mensch, Affen	Schlafkrankheit	Schwellung der Nackenlymphdrüsen, Ödeme	Arten der Gatt. *Glossina*
T. brucei rhodesiense	Mensch, im Experiment auch Ratten	Schlafkrankheit	Meningoencephalitis, Fieber, Schlafsucht	Arten der Gatt. *Glossina*
T. congolense	Wiederkäuer, Raubtiere	Nagana-Seuche	Anämie	Arten der Gatt. *Glossina*
T. cruzi	Mensch, Haustiere	Chagas-Krankheit	Ödeme, Myokarditis, Schädigungen des Zentralnervensystems	Raubwanzen-Gatt. *Triatoma* und *Rhodnius*
T. equiperdum	Pferde	Beschälseuche	Schwellung der Genitalien, Lähmungen	mechanisch bei der Kopulation
T. braziliensis	Mensch	Schleimhautleishmaniasis	Läsionen an Haut, Schleimhäuten und Knorpel	Arten der Gatt. *Phlebotomus*

http://www.spektrum.de/lexikon/biologie-kompakt/trypanosoma/12132

Kleine Protisten – große Wirkung

Warum das Zebra Streifen hat …





… und das Quagga sie wieder verlor

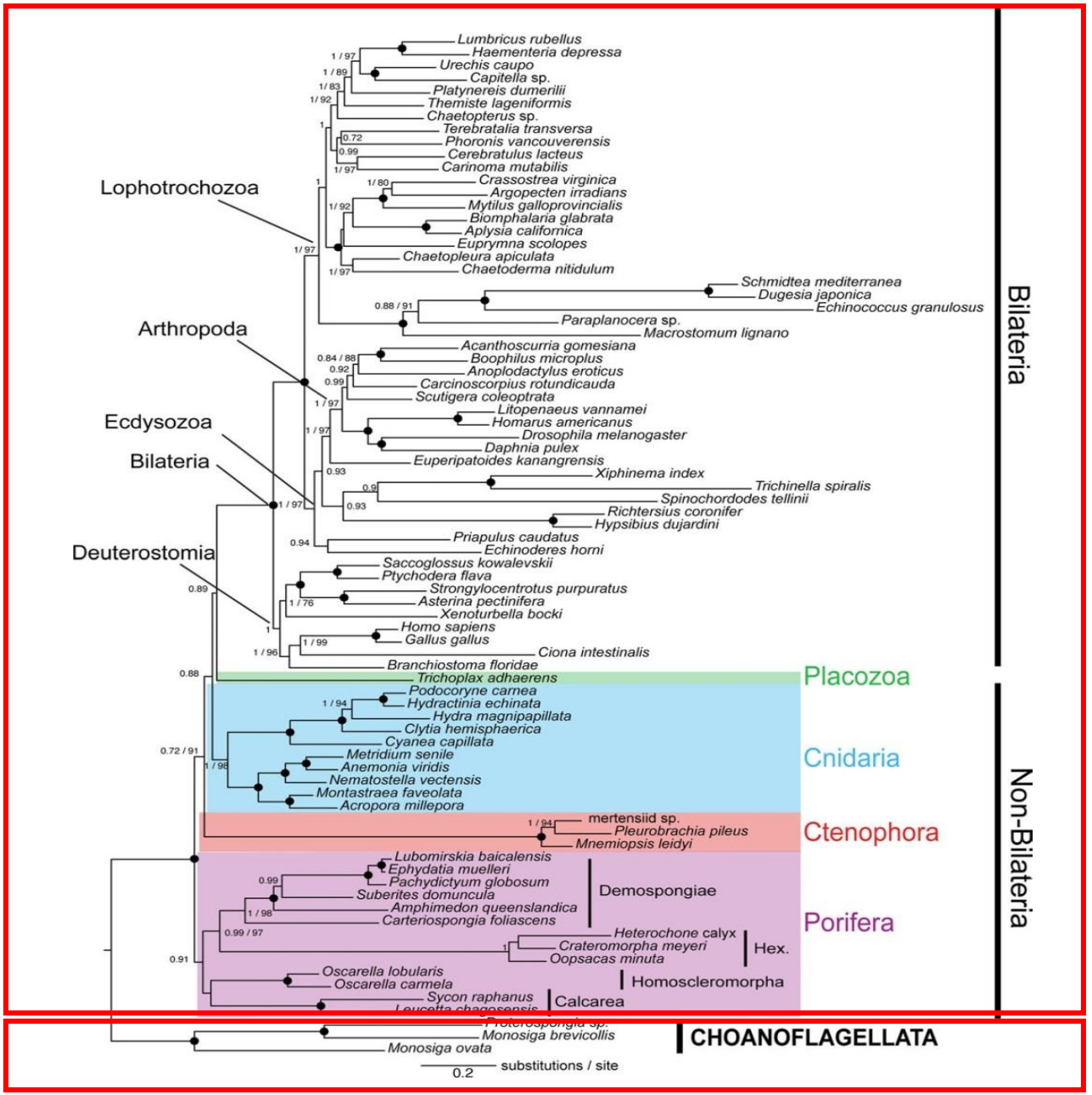
Die verwirrende Vielfalt der Namen

Stammbäume als Ordnungsversuche

- **Metazoa**

  Schwestergruppe

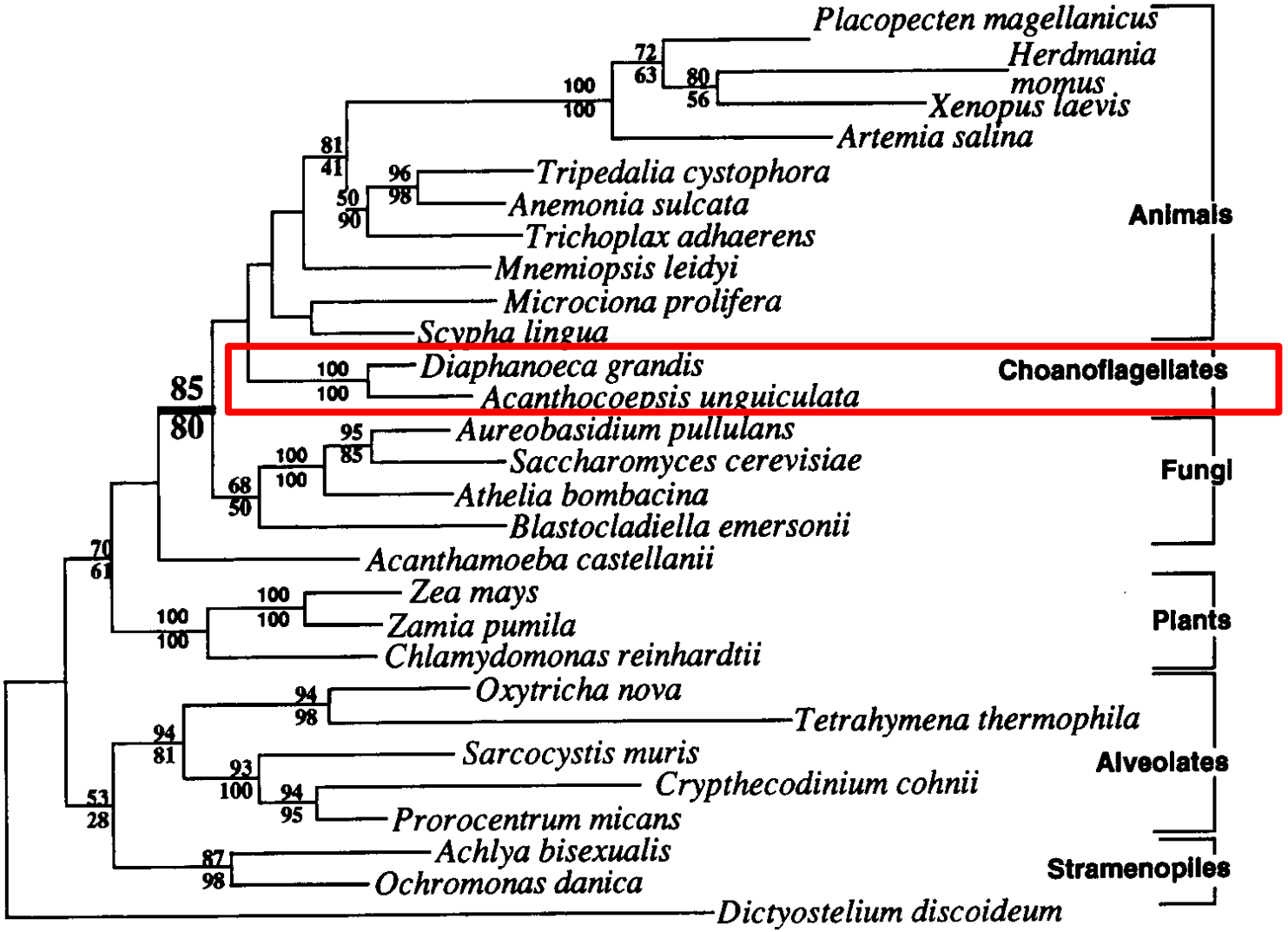
  Choanoflagellata



Pick et al. 2010. MBE

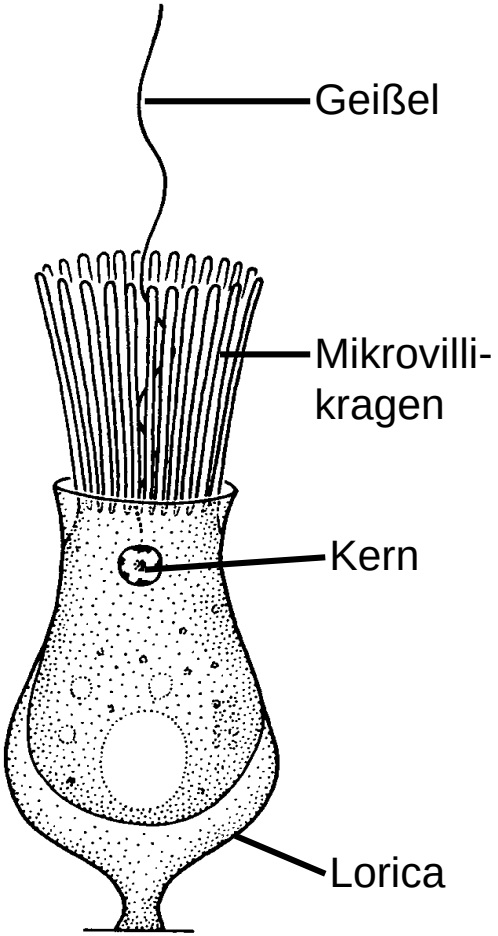
Die Schwestergruppe der Metazoa

- **Phylogenie der Eukaryota nach 18S rDNA Sequenzen**

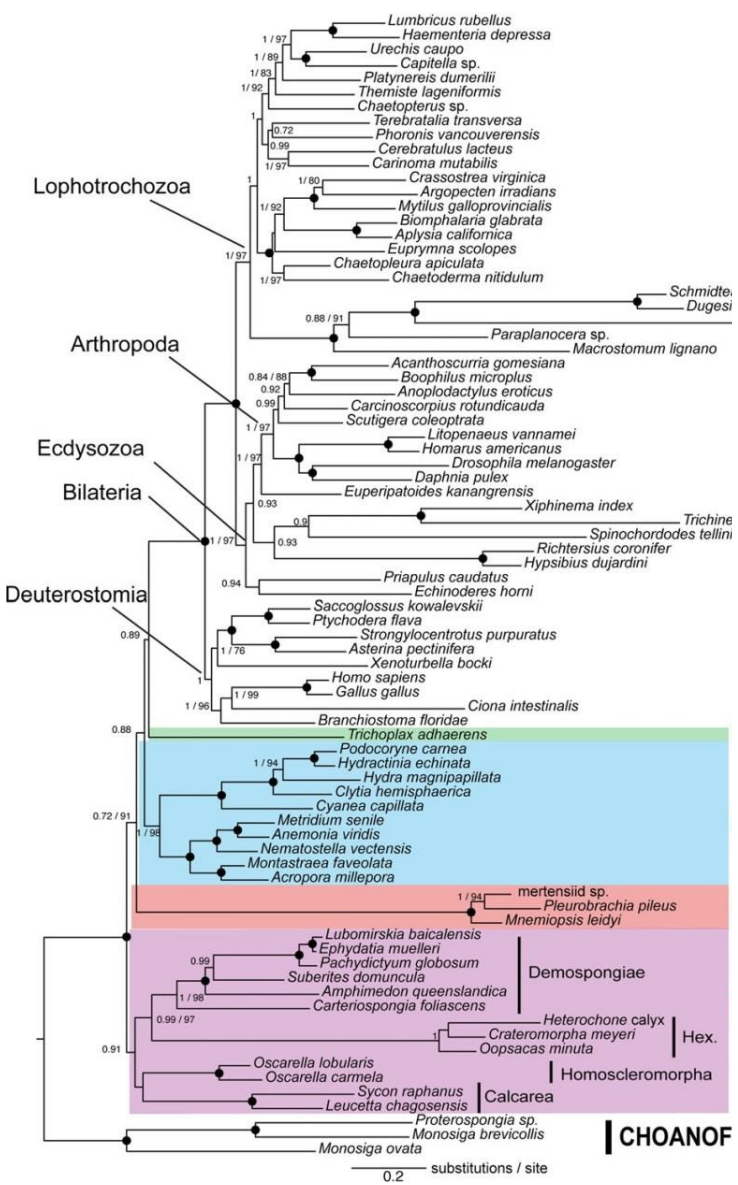


Die Schwestergruppe der Metazoa

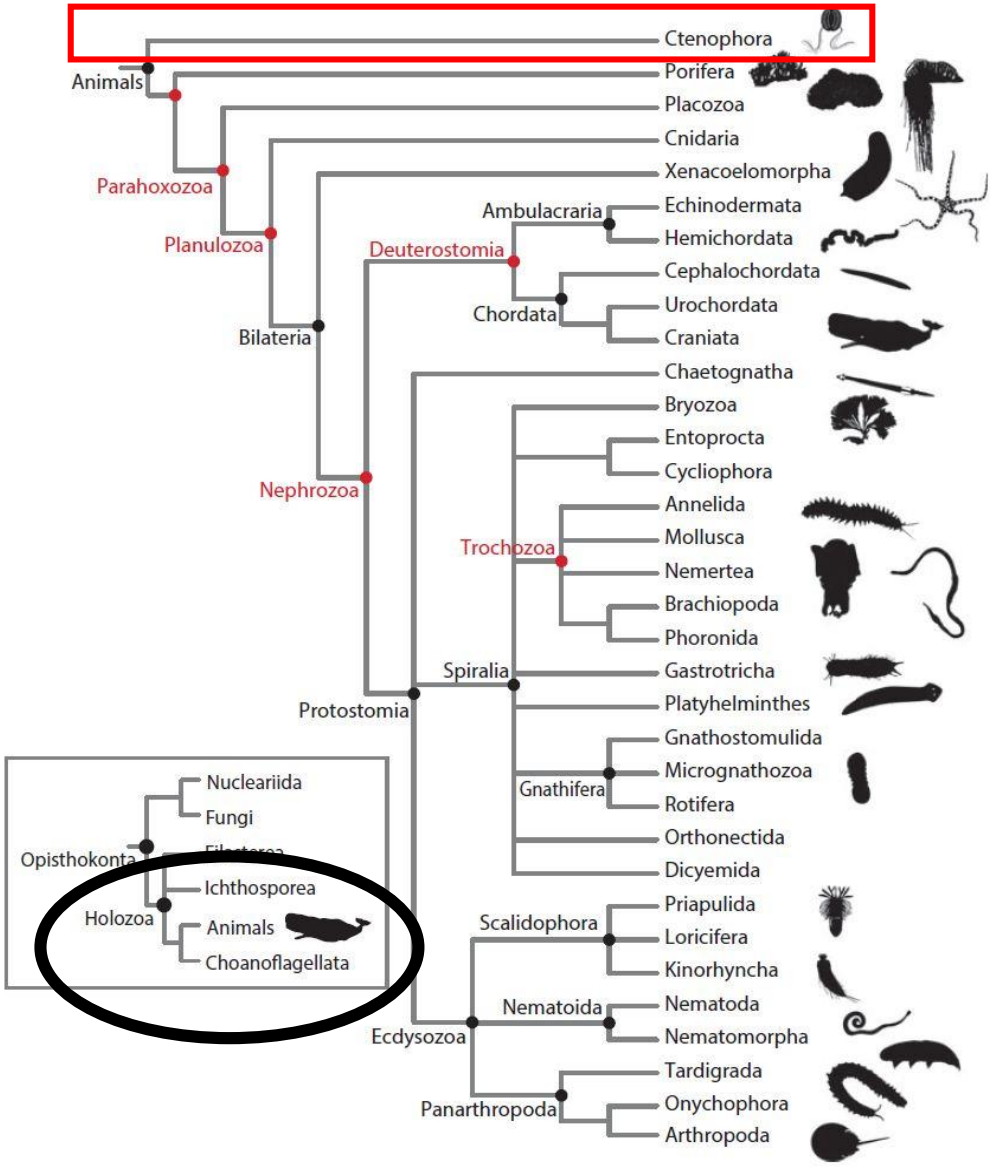
- **Choanoflagellata, Kragengeißler**



Stammbäume des Tierreichs - der jüngste Stand



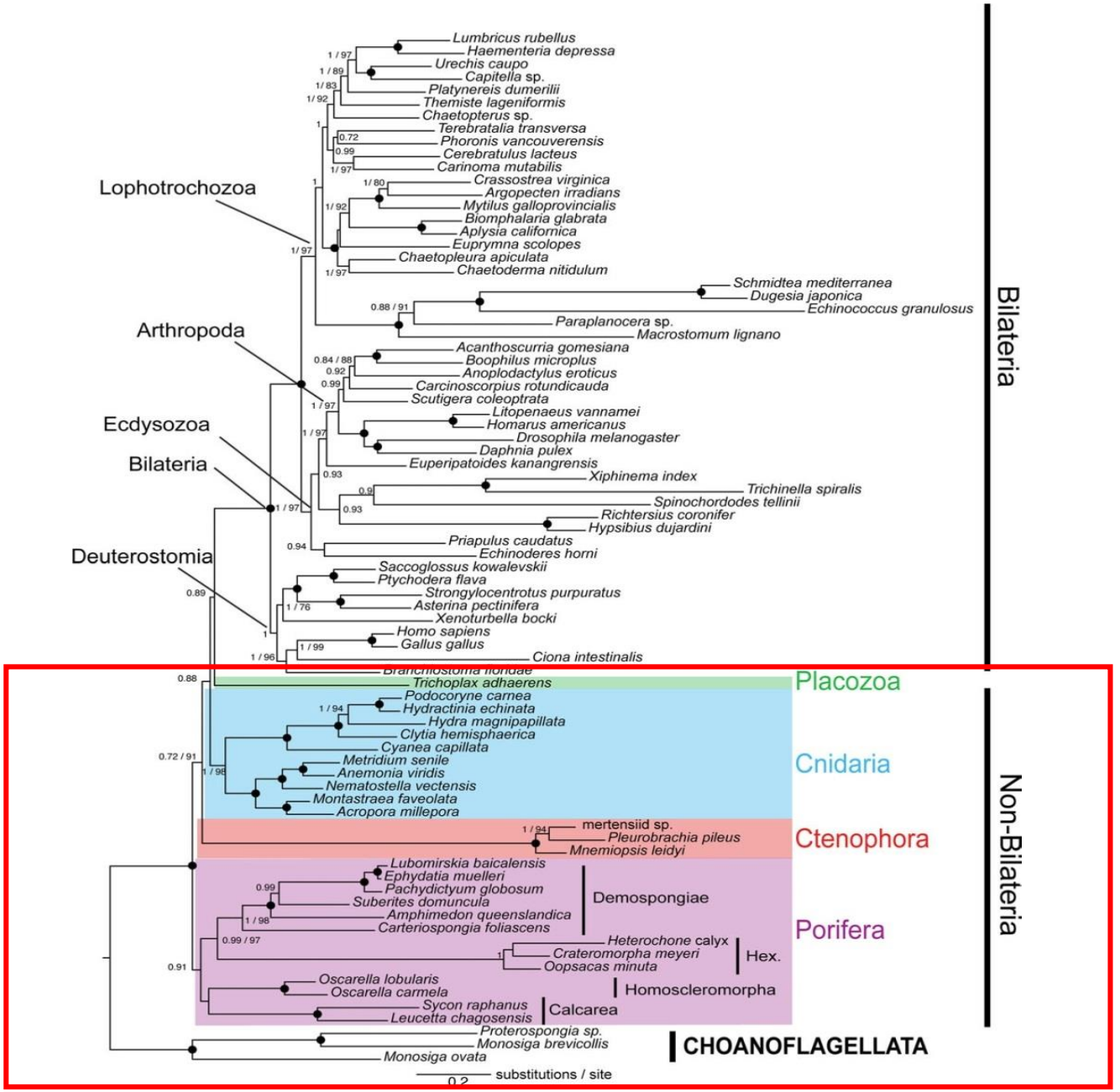
Pick et al. 2010. MBE



Dunn et al. 2014 - Annu. Rev. Ecol. Evol. Syst.

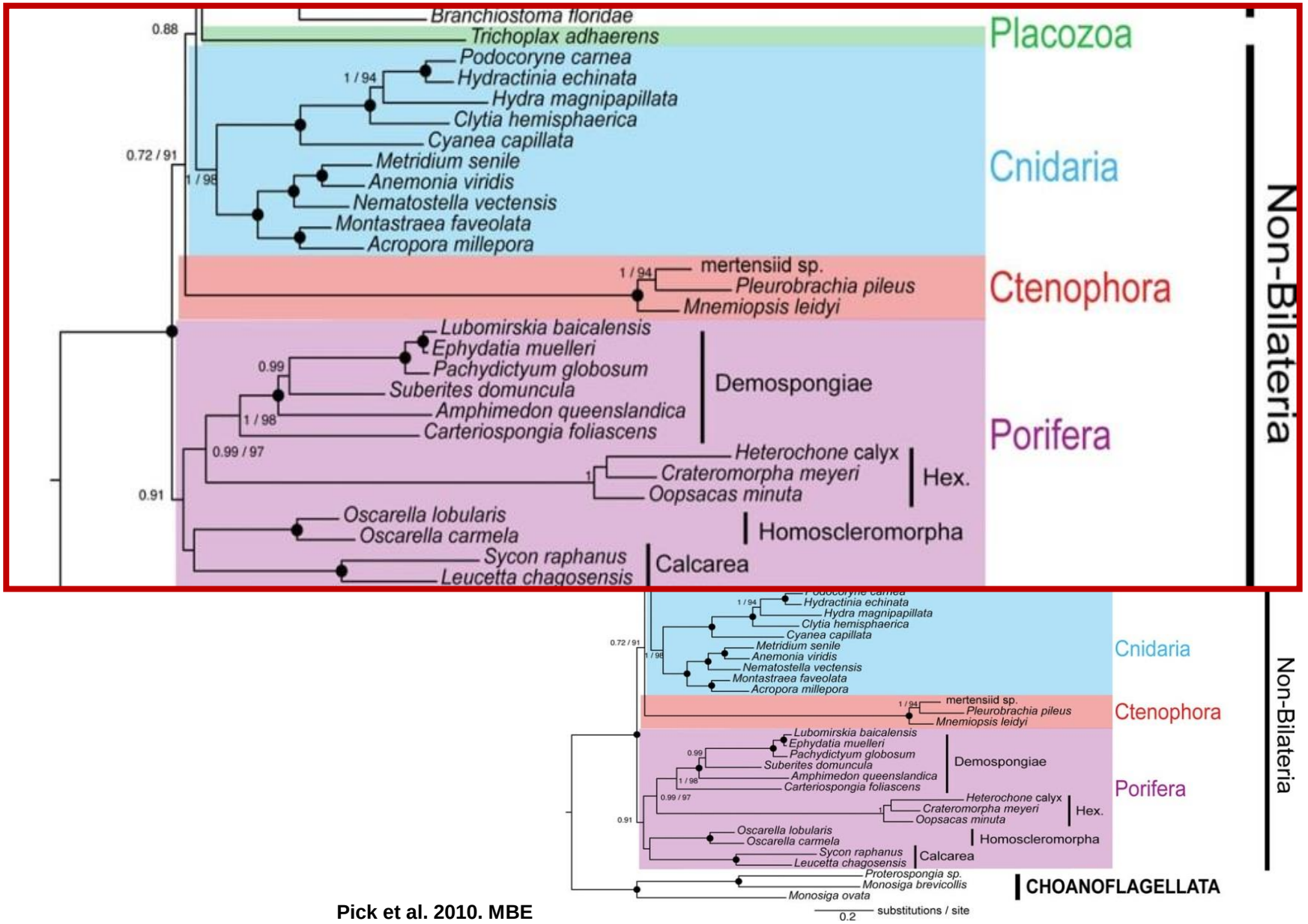
Der Stammbaum tierischen Lebens - Vielzeller

- **Metazoa**



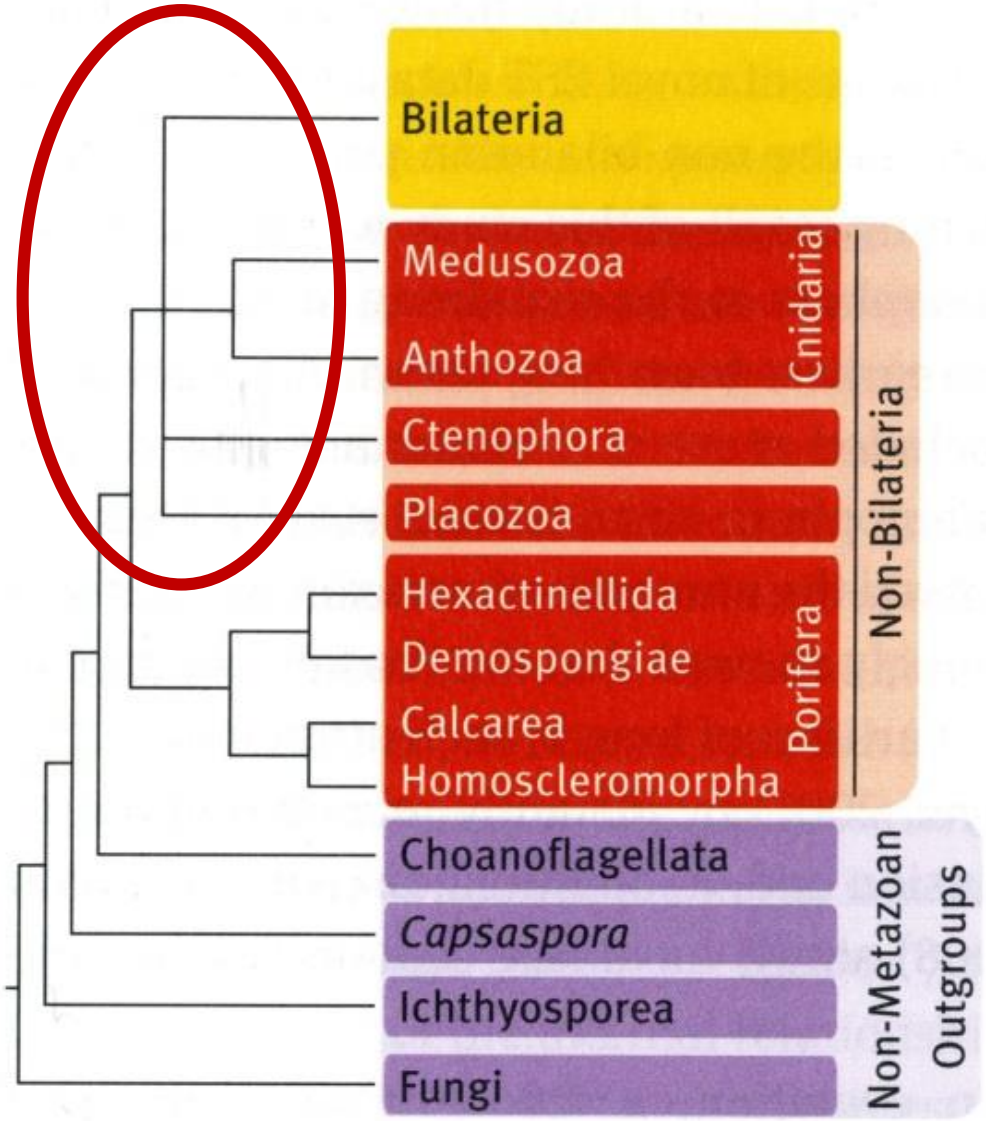
Ryan, J.F. et al. 2013. Science

Ein (!) Stammbaum der Metazoa – „Non-Bilateria"

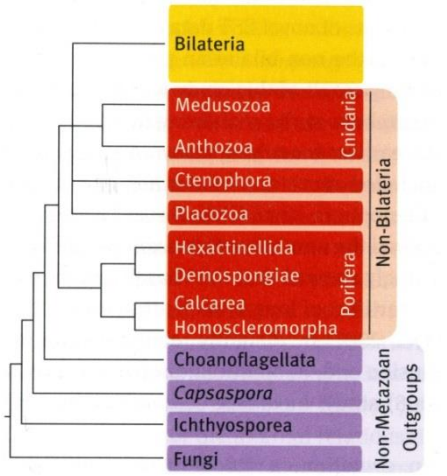


Pick et al. 2010. MBE

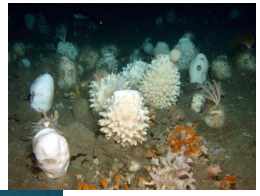
Und noch ein Stammbaum der Metazoa



Das System der Metazoa - zur Stellung der basalen Gruppen



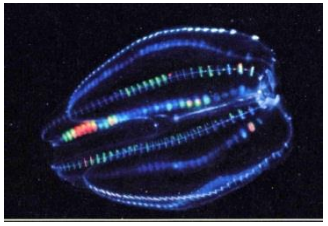
Porifera (Schwämme)



Placozoa

Cnidaria (Nesseltiere)

Ctenophora (Rippenquallen)

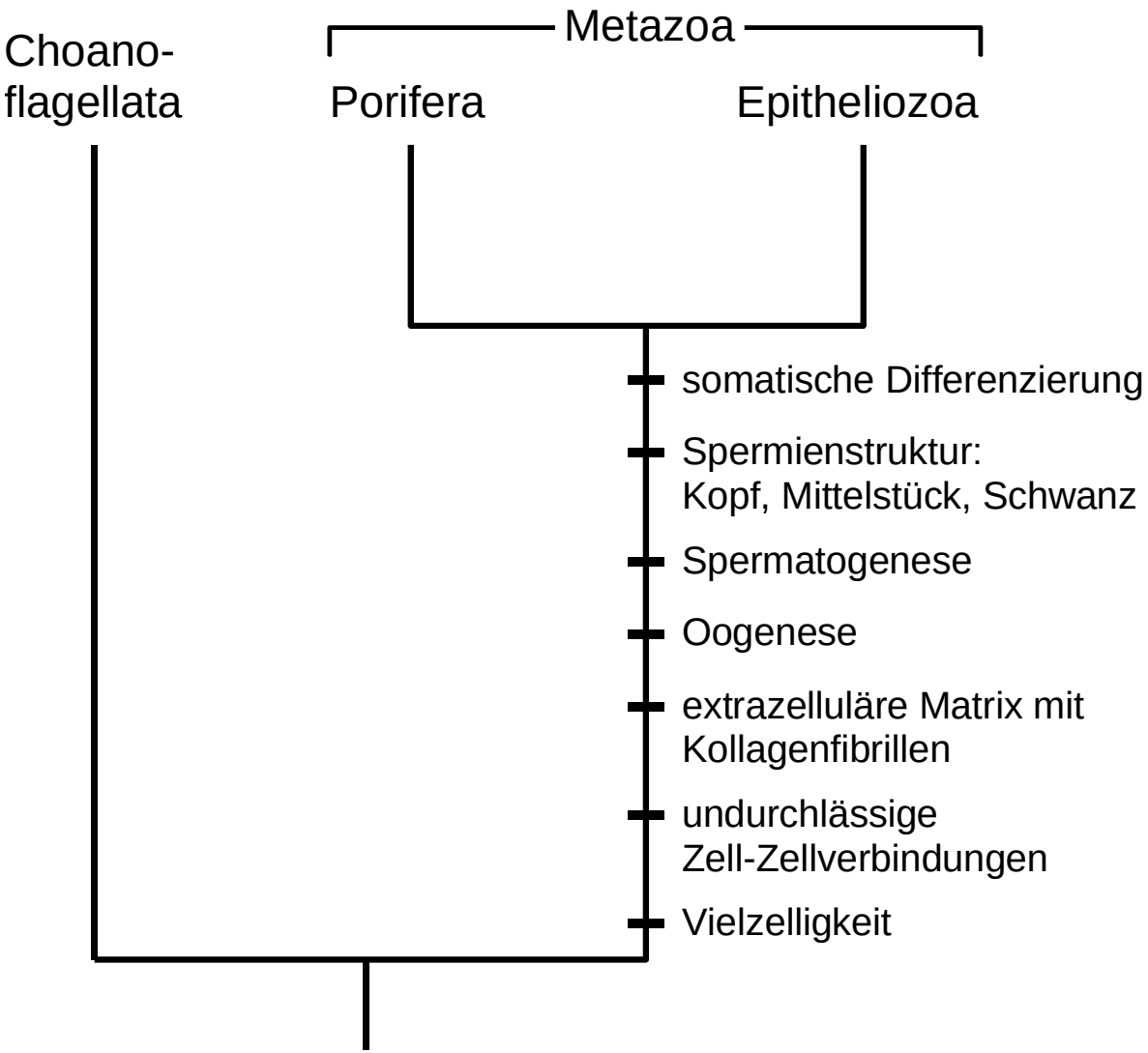


Bilateria

Autapomorphien **Metazoa**:
- Vielzelligkeit
- Ei- und Samenzellen
- Bestimmte Zell - Zellkontakte
- Ontogenese mit Radiär-furchung und Blastula

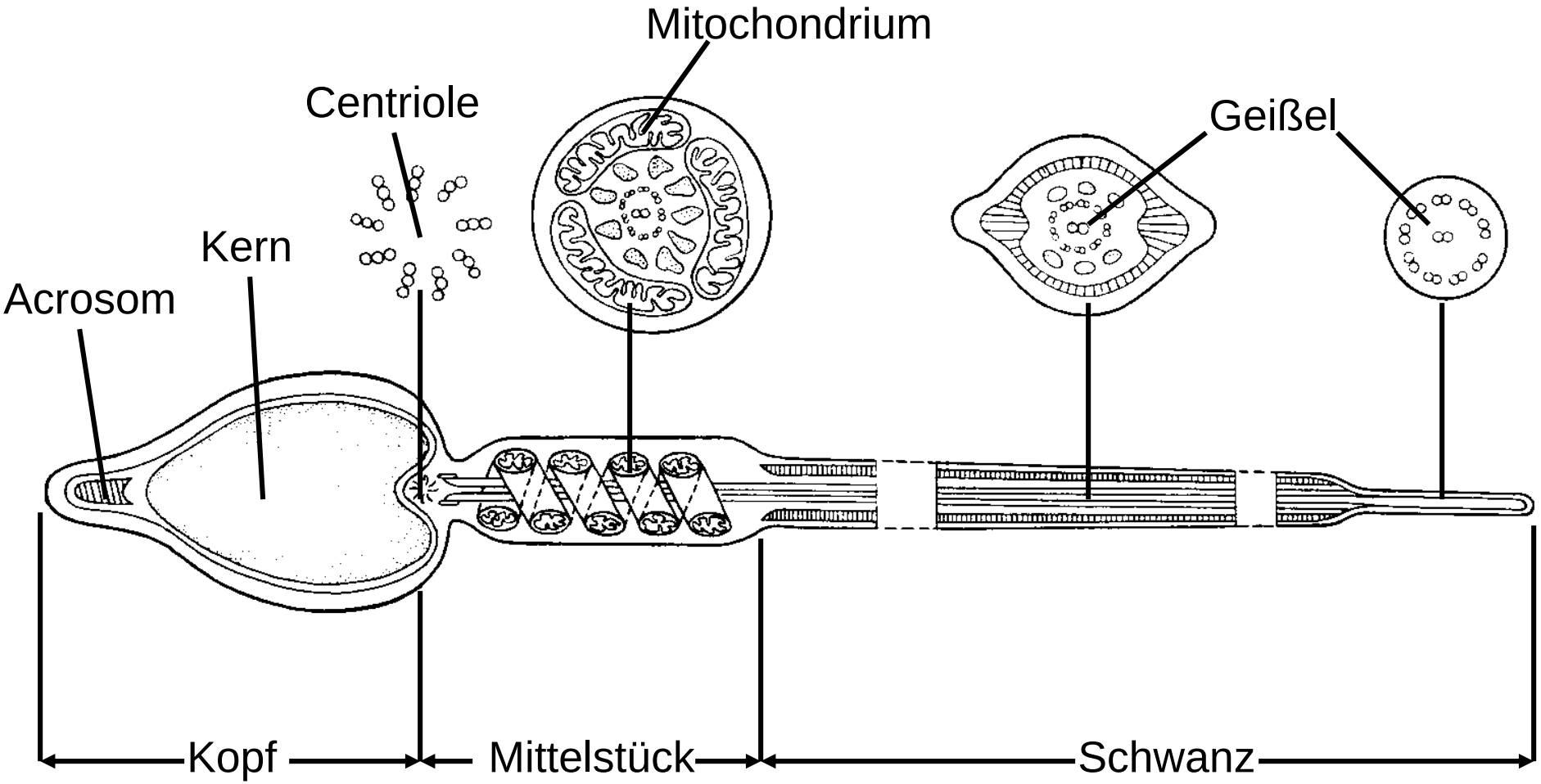
Metazoa – Die nächsten Verwandten

- **Autapomorphien der Metazoa**



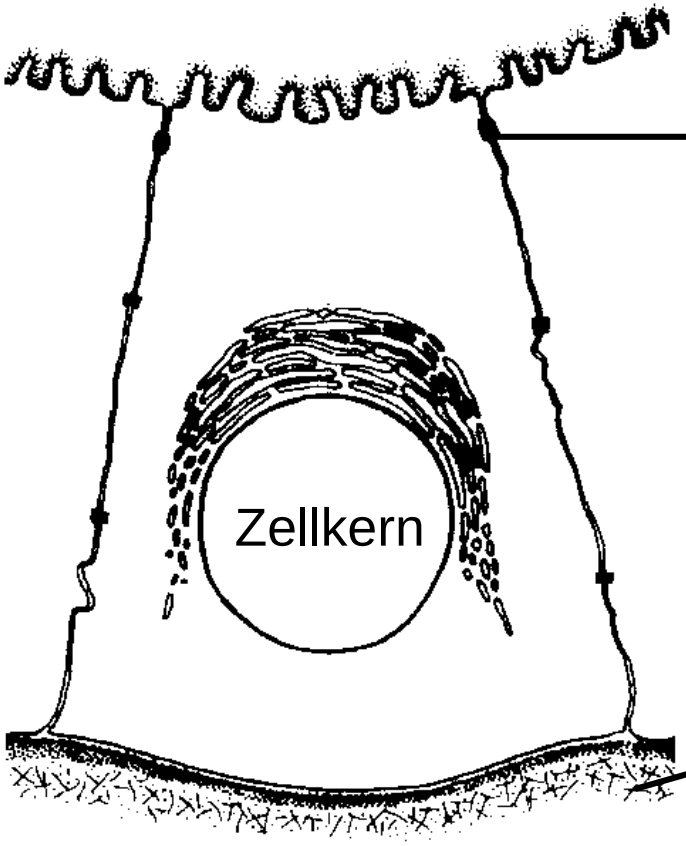
Apomorphie der Metazoa (i)

- **Spermienstruktur**



Apomorphie der Metazoa (ii)

- **besonderer Bau der Metazoenzelle – zwei Apomorphien**



undurchlässige
Zell-Zellverbindungen
(septate / tight junctions)

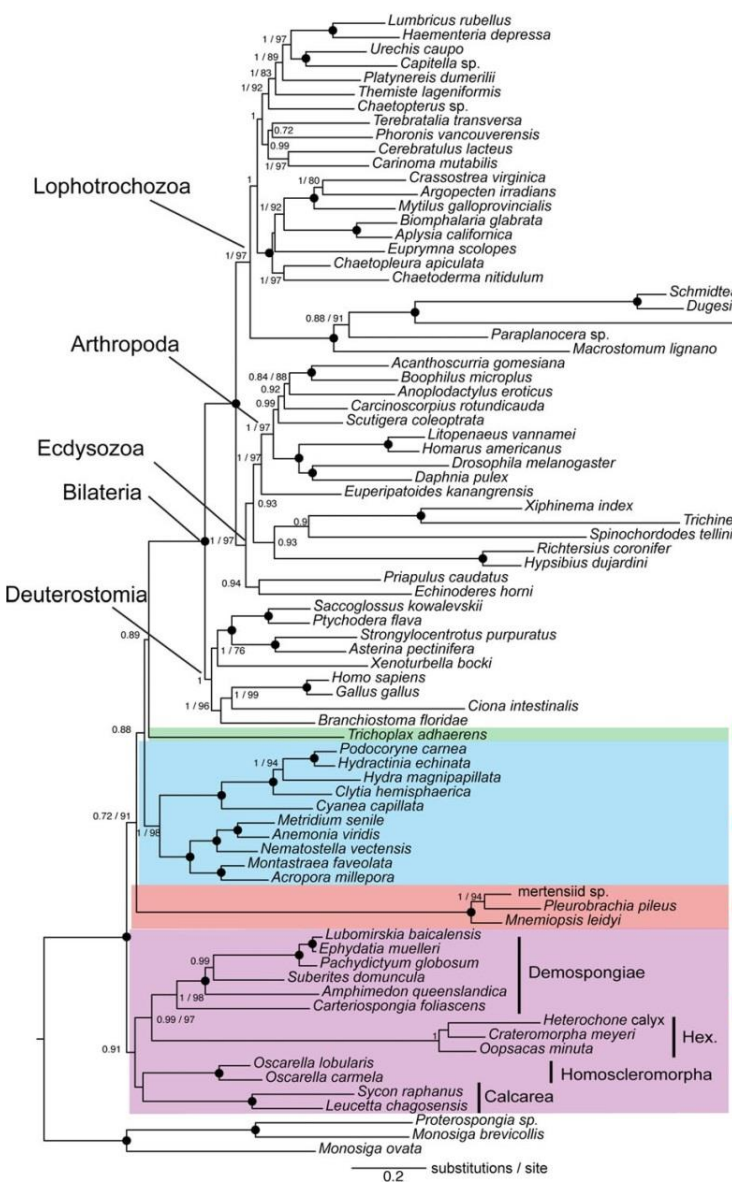
extrazelluläre
Matrix mit
Kollagenfibrillen

Die verwirrende Vielfalt der Namen

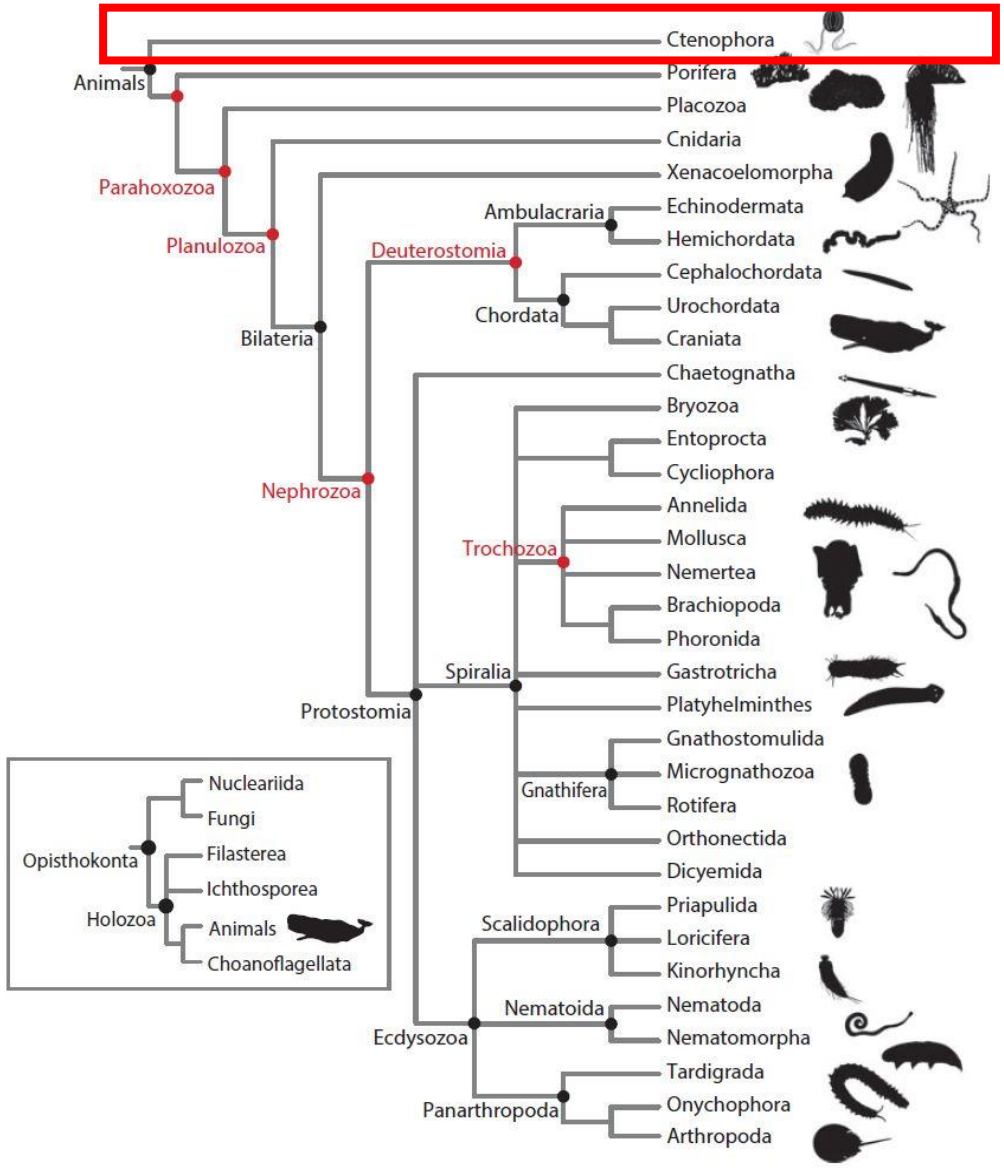
Ctenophora – Rippenquallen als Rätseltiere der Systematik

Mnemiopsis leidyi

Stammbäume des Tierreichs - der jüngste Stand

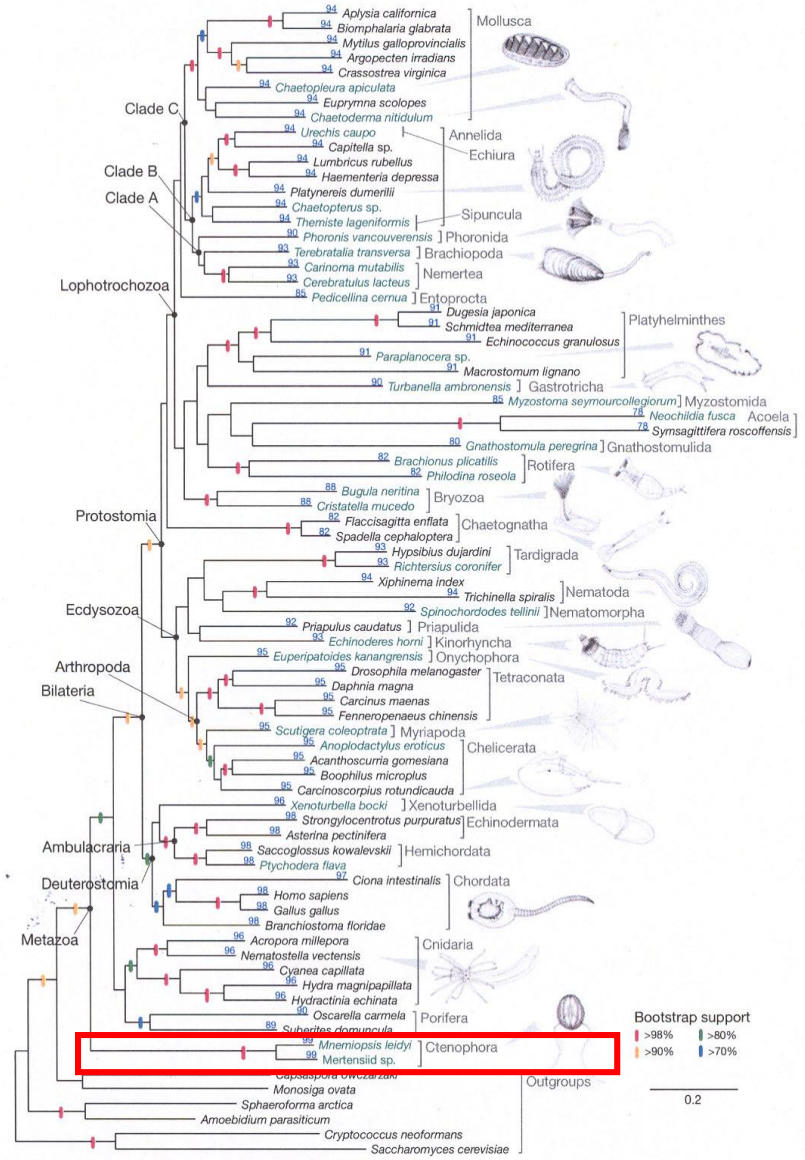


Pick et al. 2010. MBE

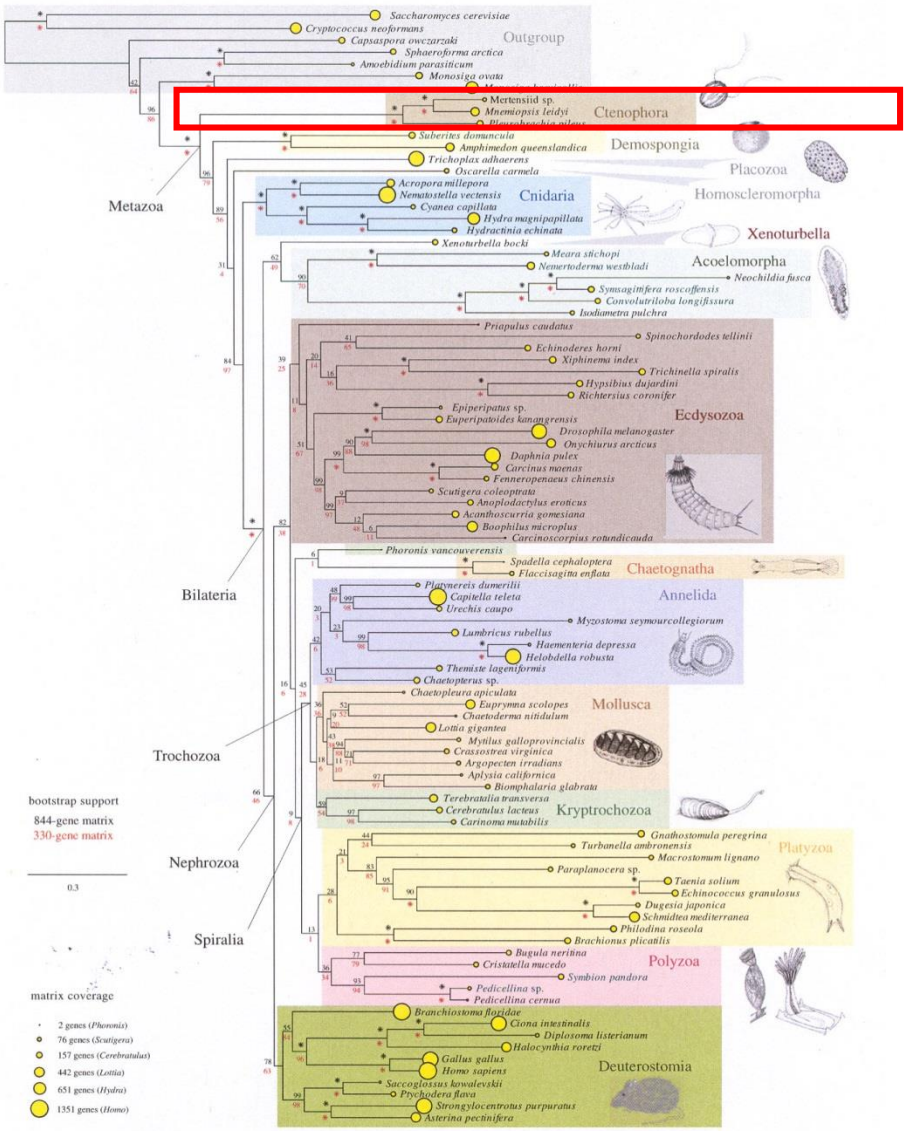


Dunn et al. 2014 - Annu. Rev. Ecol. Evol. Syst.

Wer kam zuerst – Rippenqualle oder Schwamm ?

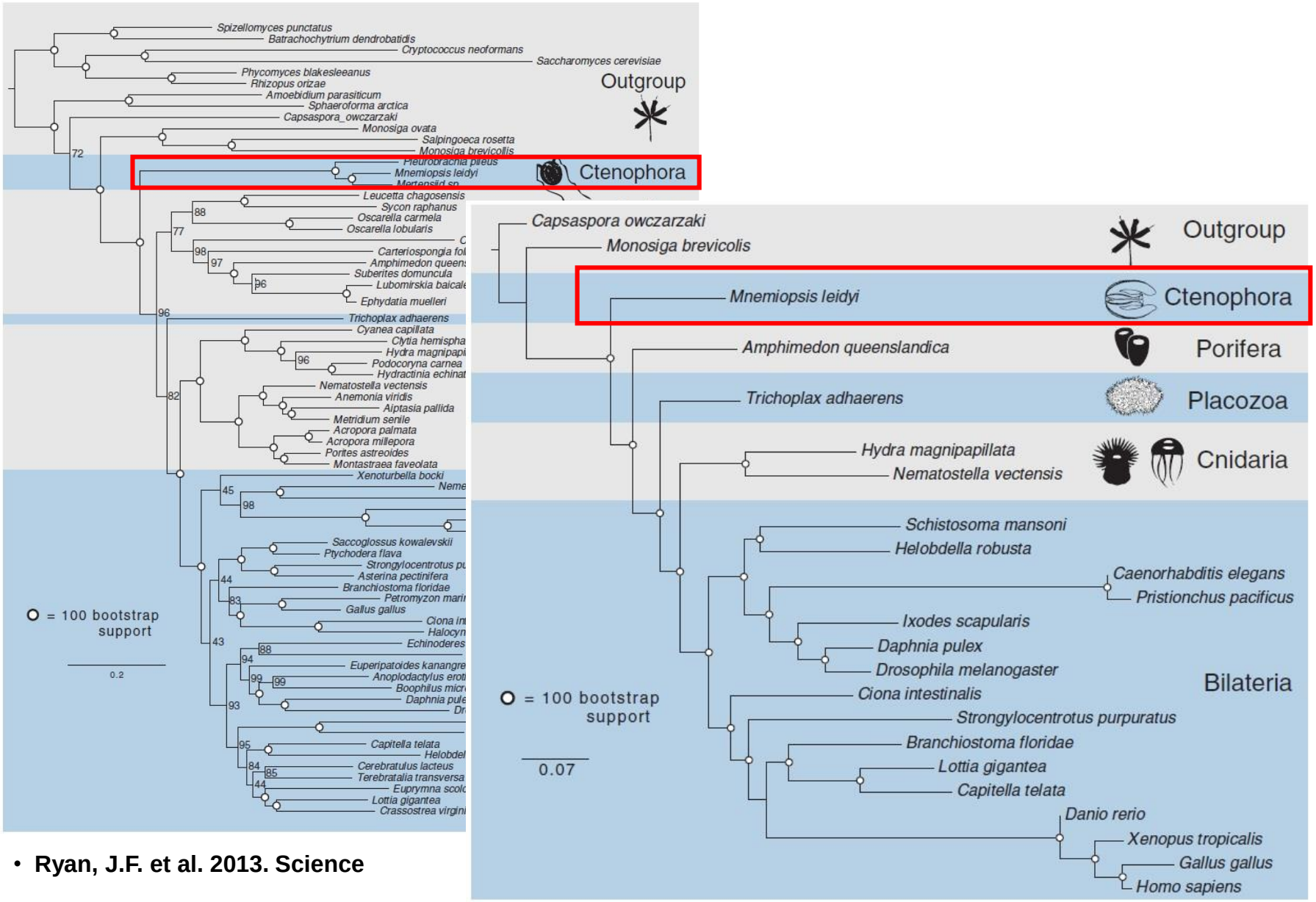


- Dunn et al. (2008)



- Hejnol et al. (2009)

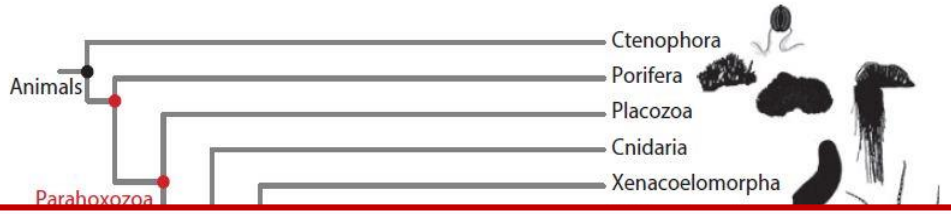
Wer kam zuerst – Rippenqualle oder Schwamm ?



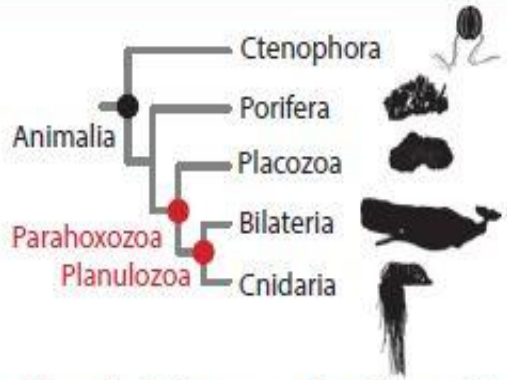
- **Ryan, J.F. et al. 2013. Science**

Das phylogenetische System des Tiereichs

- **Rätseltiere ???**

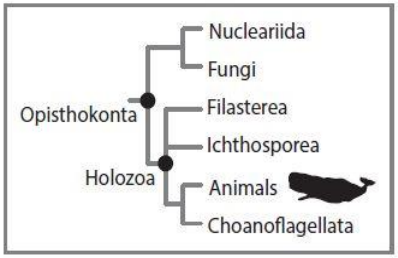


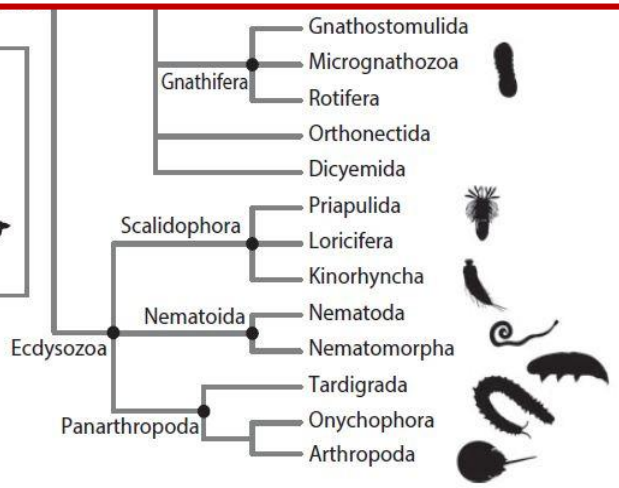
a The root of the animal tree



Ctenophora is sister group to other animals
Ryan et al. (2013)

Porifera is sister group to other animals
Philippe et al. (2009)



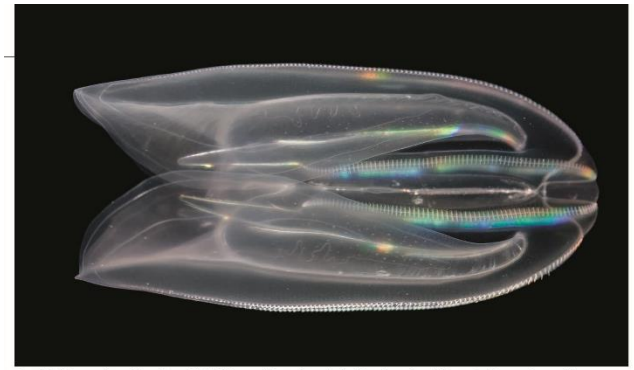


Dunn, C.W. et al. 2014. Annu. Rev. Ecol. Evol. Syst.

Ctenophora – Rippenquallen als Rätseltiere der Systematik

Unabhängige Urmünder ?

- *„butthole = finest evol. innovation“*



***Science* – März 2016**

NEWS | IN DEPTH

olooza capture the creatures as they ingest tiny crustaceans and zebrafish genetically engineered to glow red with fluorescent protein. Because comb jellies are translucent, the prey can be seen as it circulates through a network of canals lacing the jellies' bodies. Fast-forward, and 2 to 3 hours later, indigestible particles exit through the pores on the rear end. Browne also presented a close-up image of the pores, highlighting a ring of muscles surrounding each one. "This is a sphincterlike hole," he told the audience.

"Looks like I've been wrong for 30 years," said George Matsumoto, a marine biologist at Monterey Bay Aquarium Research

a, after
on't see
added.
he bio-
bowel
observe
meal.
their
vomit-
, or the

s, comb
animals
considered to have one hole, including sea anemones, jellyfish, and possibly sea sponges
's as-yet
tep-wise
om one
on.
b jellies
e pores
her ani-
f years.
xit hole
ent ani-
became
sponges.
sponge

stuck to a rock, suggests Matsumoto, it's better to push waste back into the current rather than below.

he latter
lies acti-
ing their
growing
are dif-
inspeak-
nsidered
ng sup-
onal no-
ion, and
n Kocot,
niversity

Amy Maxmen is a writer based in Berkeley, California.

sciencemag.org SCIENCE

Published by AAAS

By Amy Maxmen

lies, or ctenophores, now threaten to upend the standard view of the evolution of the

ded f

cies alive today, ranging from earthworms

this video, they won't believe it."

hole leading to a saclike gut. In 1880, the Ger-

- **Protostomia – Urmund zum Mund**

  Eingang = Ausgang

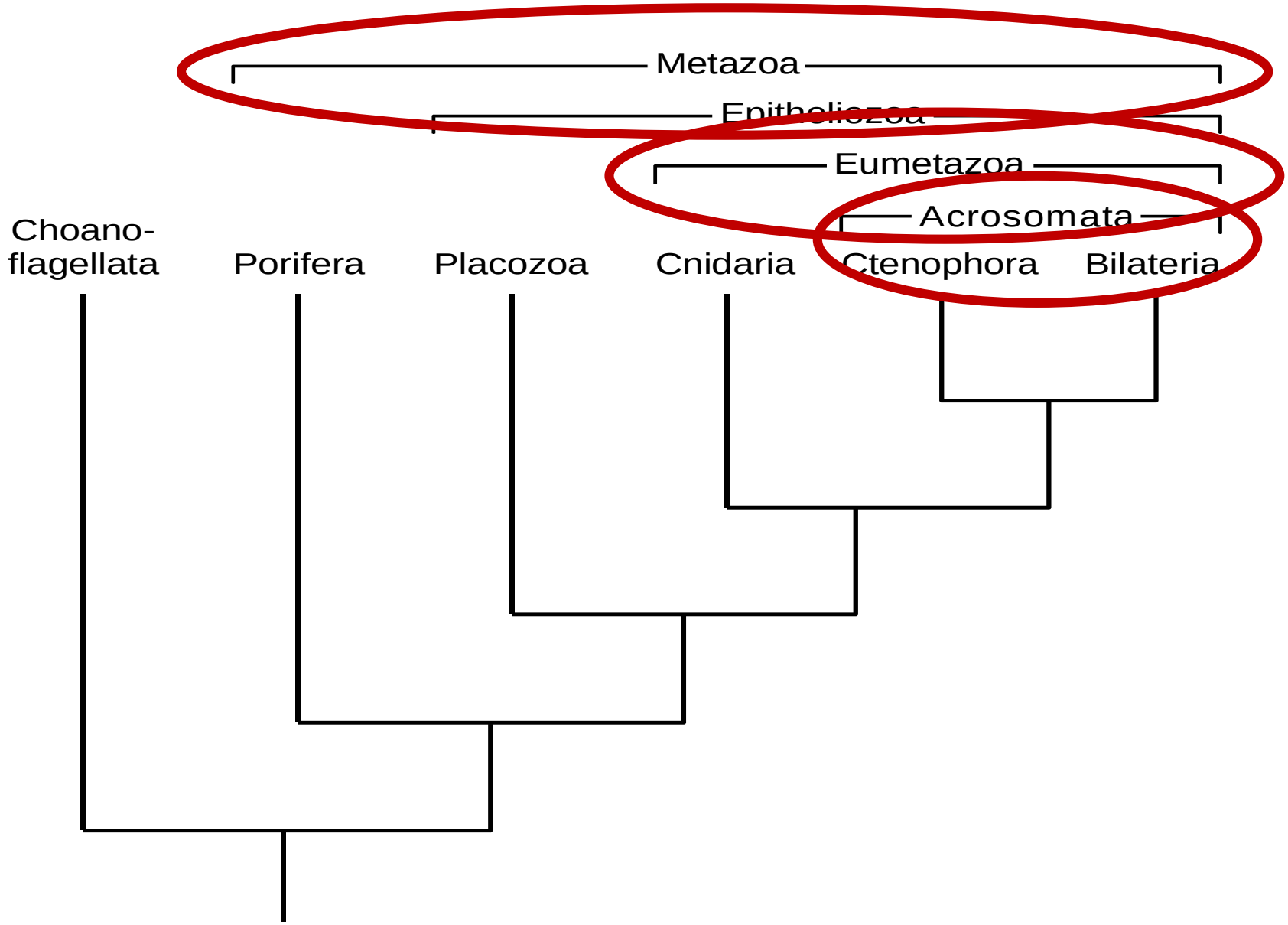
- **Deuterostomia – Urmund zum After; Mund sekundär neu**

  Essen & Verdauen

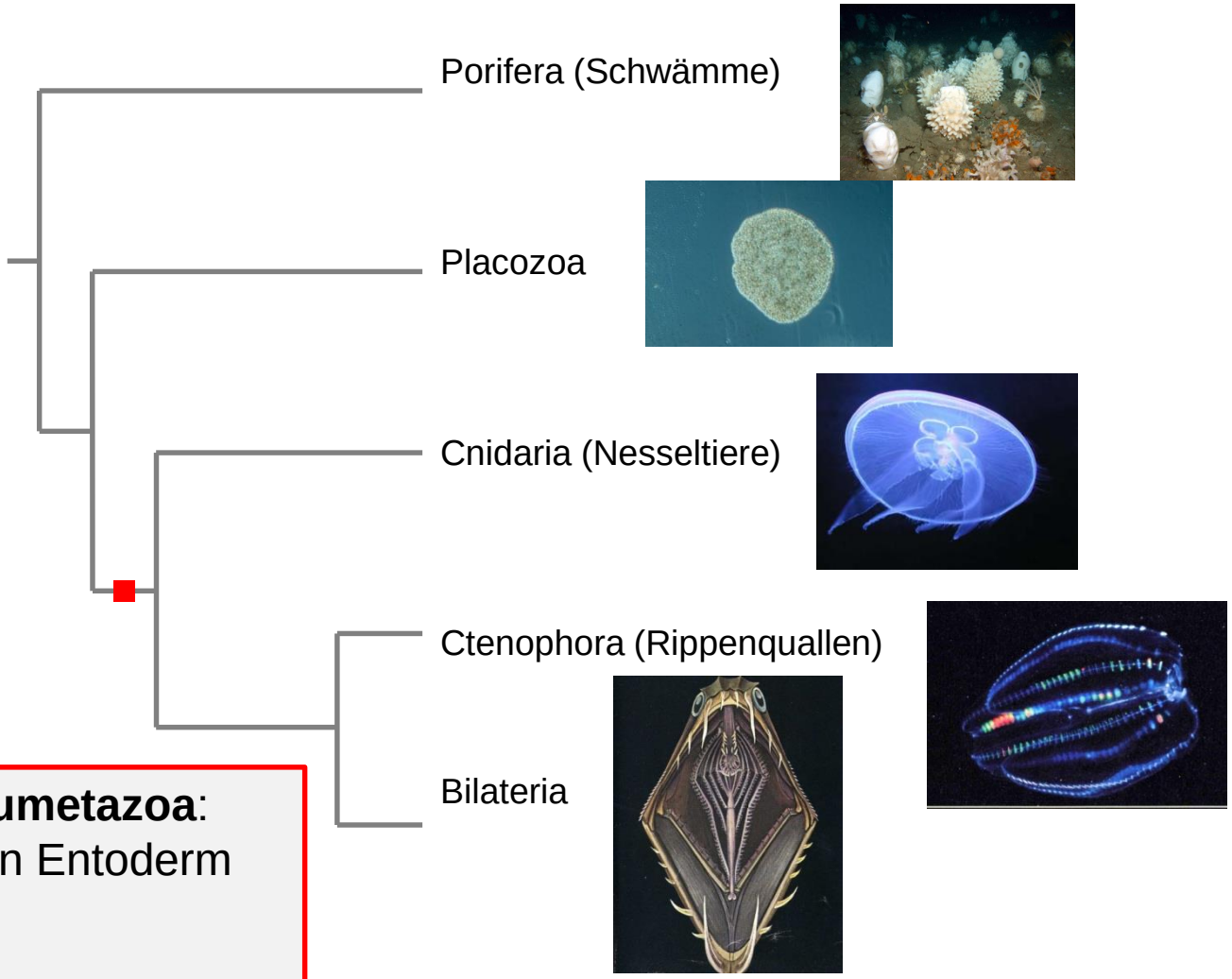
- **C. Chun (1880) – W. Browne (2016):**

  Ctenophora mit After-ähnlichen Poren – unabhängig ?

Hypothese zur Stellung der basalen Gruppen

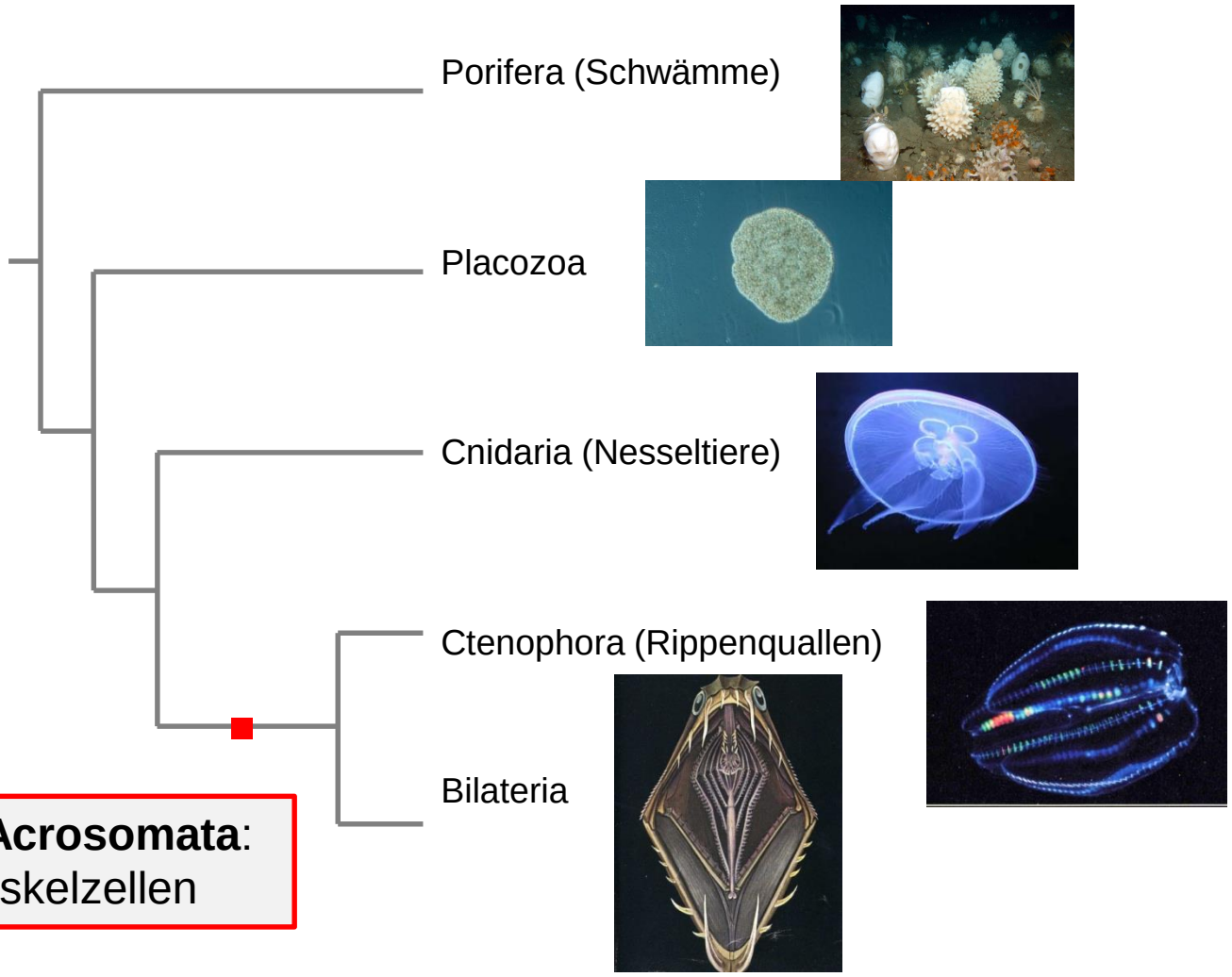


Das System der Metazoa - zur Stellung der basalen Gruppen



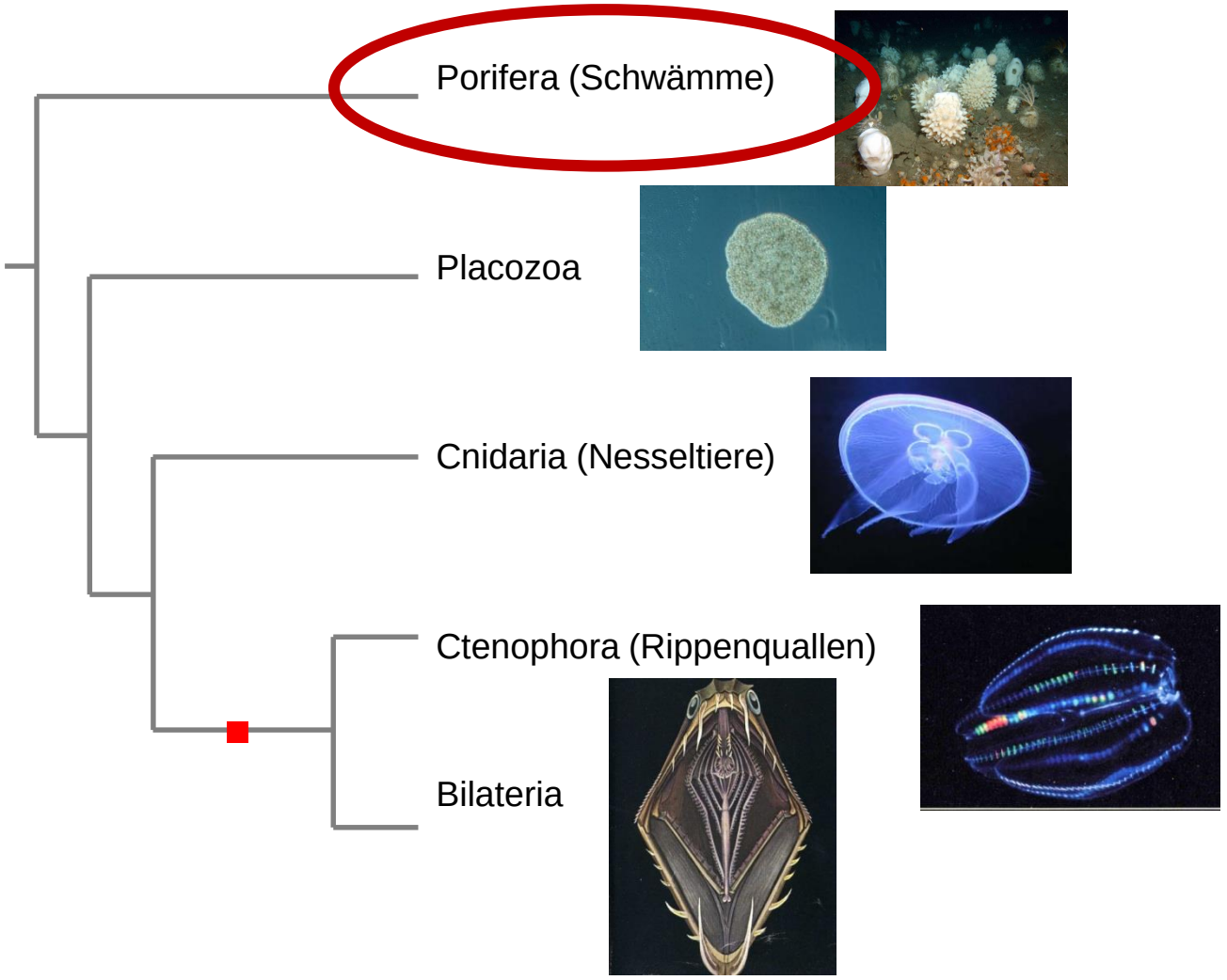
Autapomorphien **Eumetazoa**:
- Differenzierung in Entoderm und Ektoderm
- Nervenzellen
- Epithelmuskelzellen

Das System der Metazoa - zur Stellung der basalen Gruppen

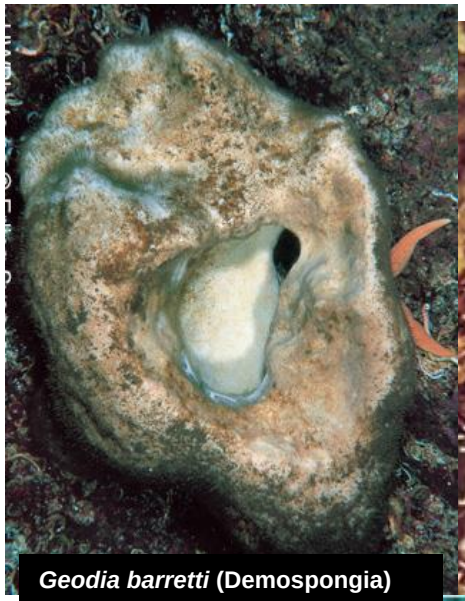


Autapomorphien **Acrosomata**:
- Echte Fasermuskelzellen

Das System der Metazoa - zur Stellung der basalen Gruppen



Porifera - Schwämme



Geodia barretti (Demospongia)

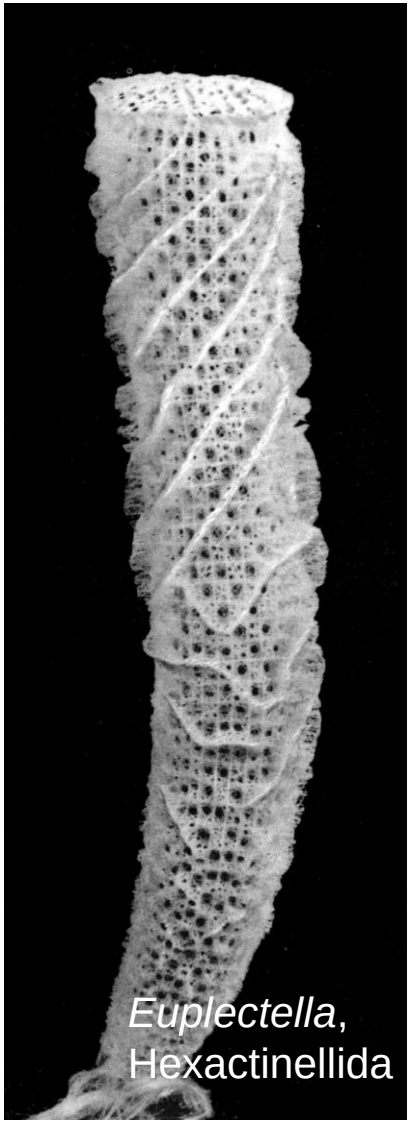
Hippospongia sp. (Demospongia)

Spongilla fluviatilis (Demospongia)

Verongia sp. (Demospongia)

Spongia officinalis (Demospngia)

Porifera - Schwämme

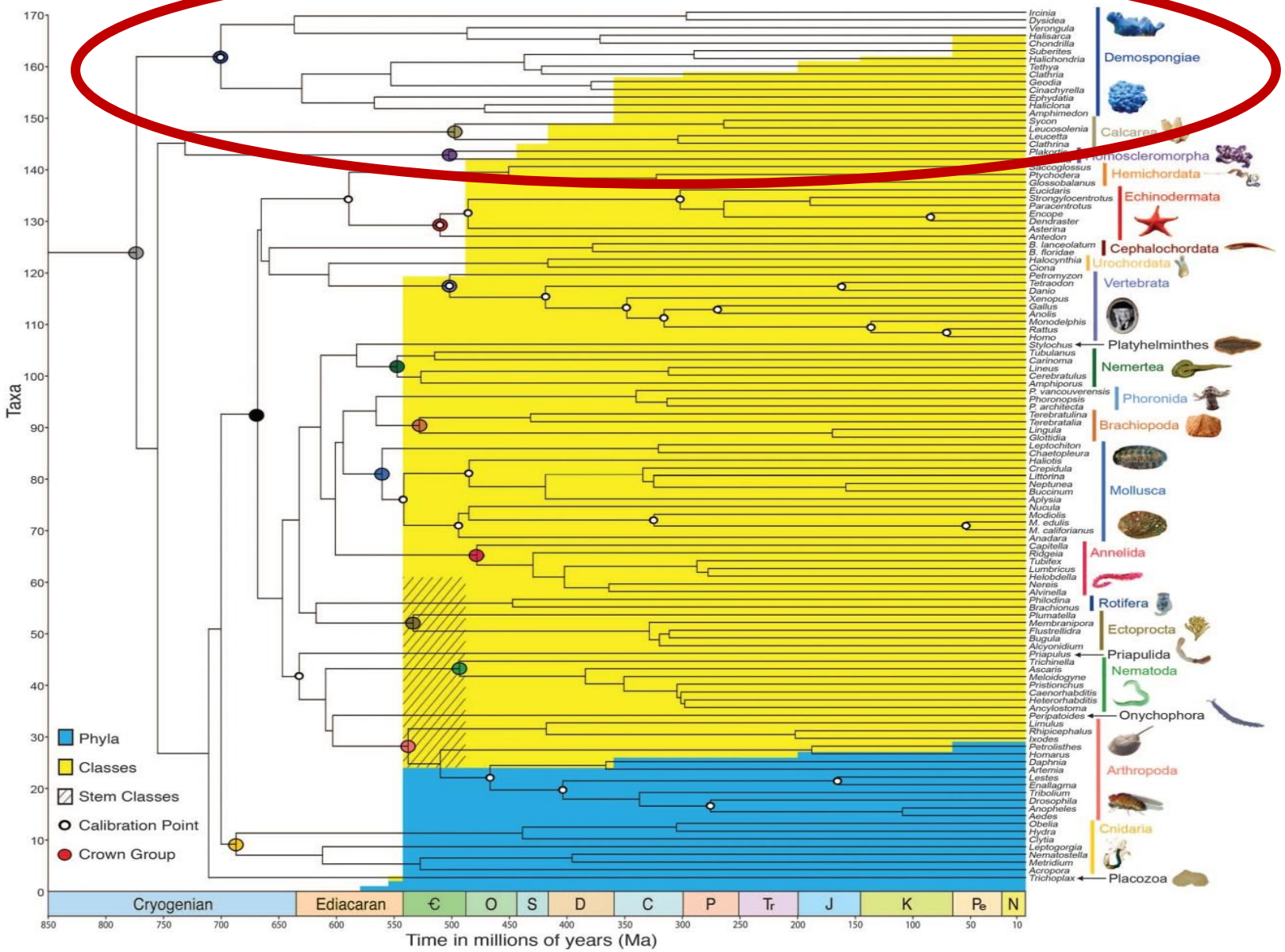


Euplectella,
Hexactinellida

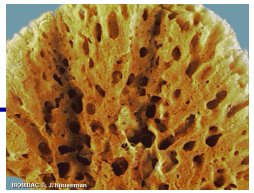
Hexactinellida

Schwämme - Fossil belegte „evolutive Dauerläufer"

- **Ursprung im Kambrium** >540 mya



Porifera - Schwämme



- **Systematik:**

Calcarea (Kalkschwämme)

- ca. 500 Arten, marin

- mit kalkigen Spicula

Sycon ciliatum

Porifera - Schwämme

- **Systematik:**

Demospongiae

- >7000 Arten, marin und im Süßwasser

- mit Hornskelett (Badeschwamm) oder kieseligen Spicula (SiO_2)

Spongia officinalis

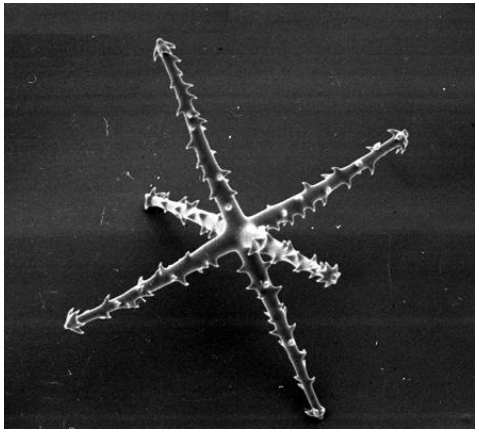
Porifera - Schwämme

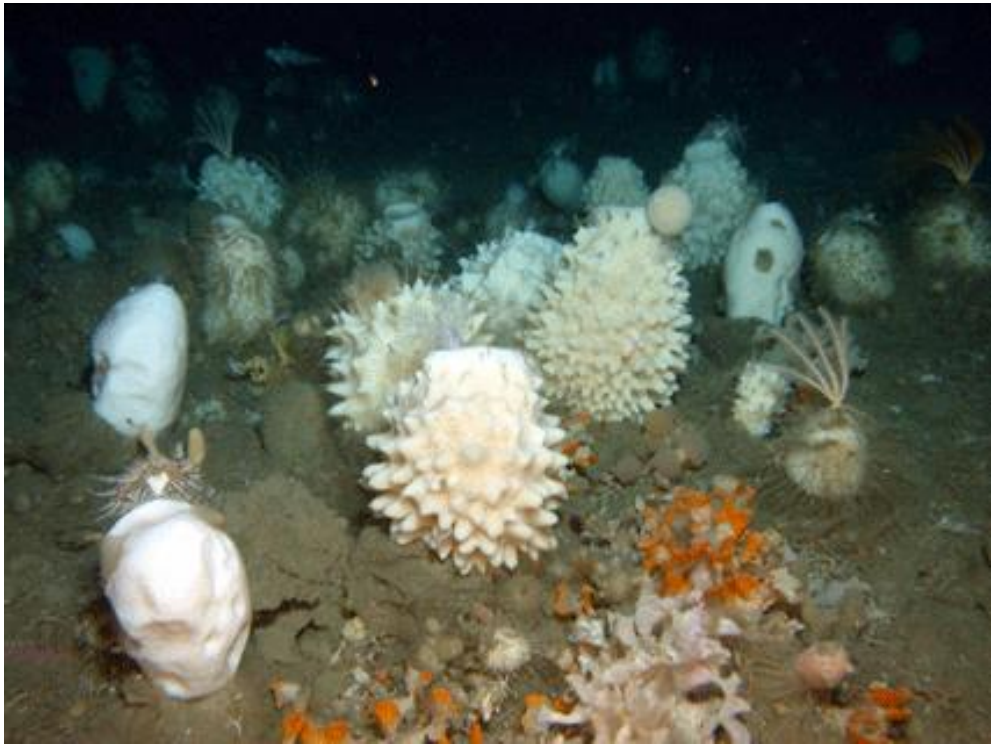
- **Systematik:**

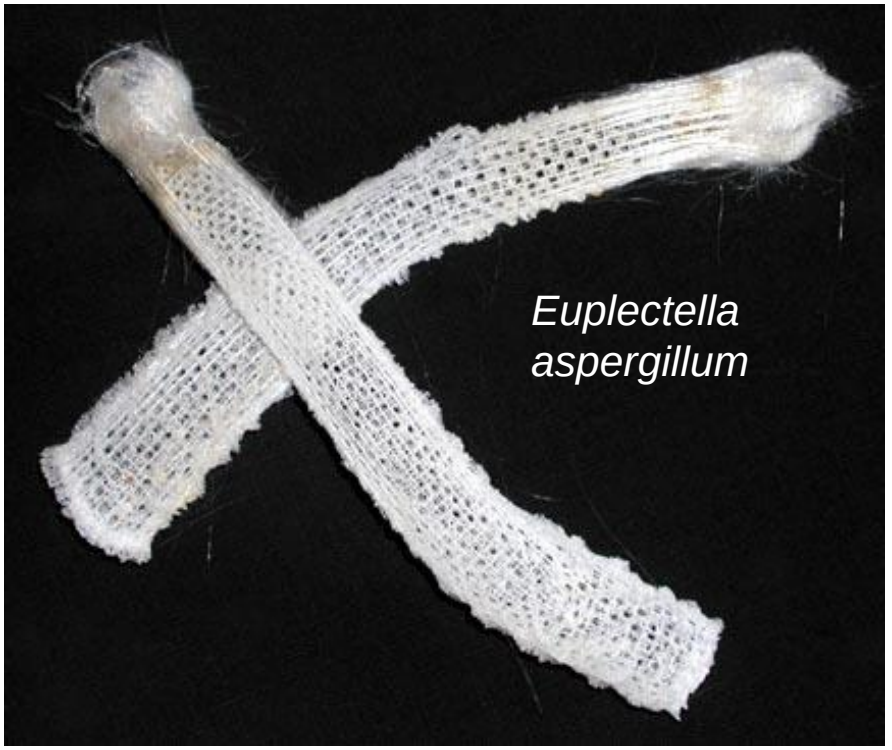
Hexactinellida (Glasschwämme)

- ca. 400 Arten, marin (meist Tiefsee)

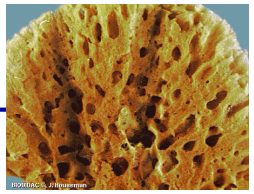
- mit kieseligen Spicula



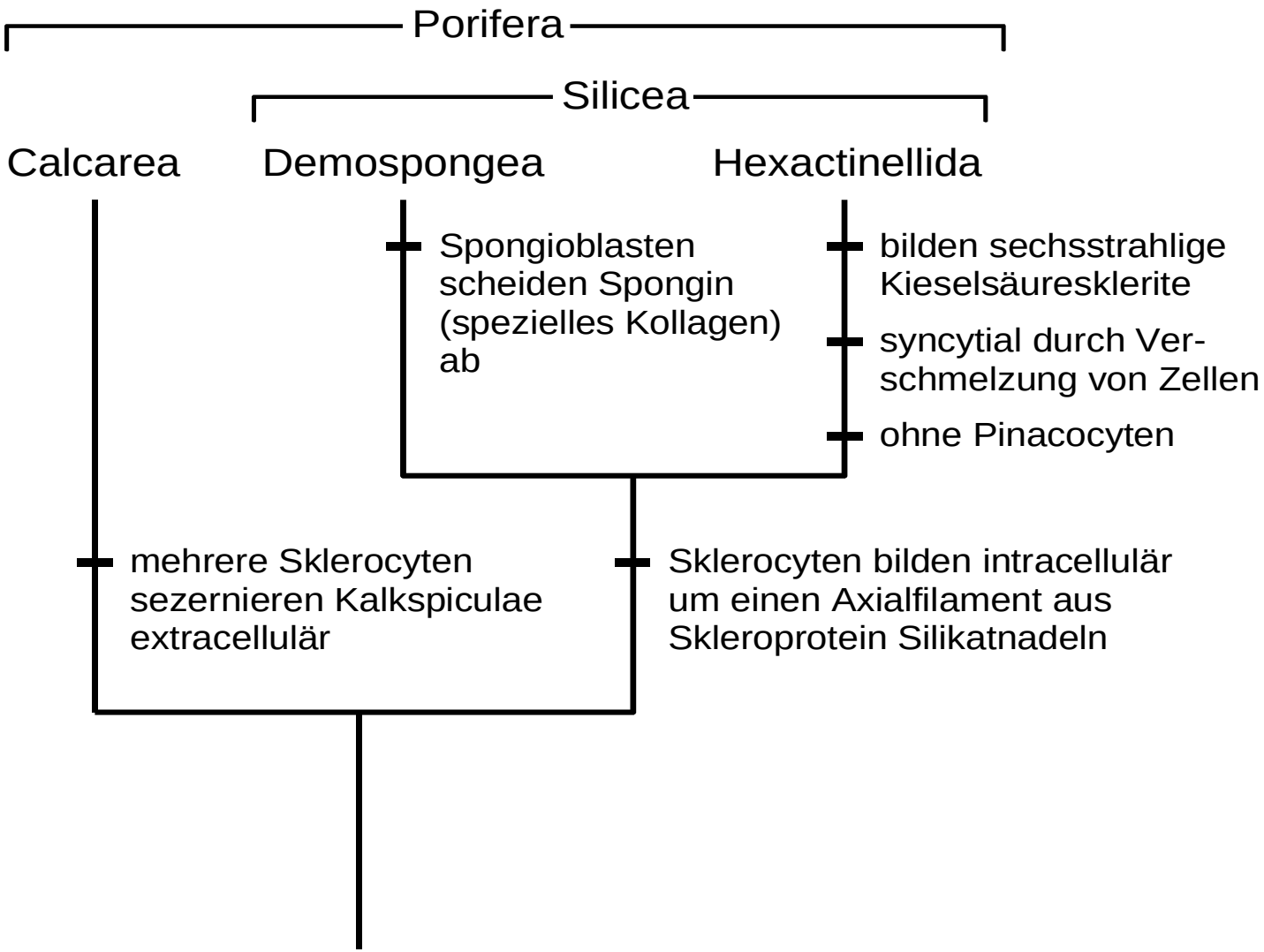




Porifera - Schwämme



- **Zur verwandtschaftlichen Gliederung der Schwämme**



Porifera - Schwämme

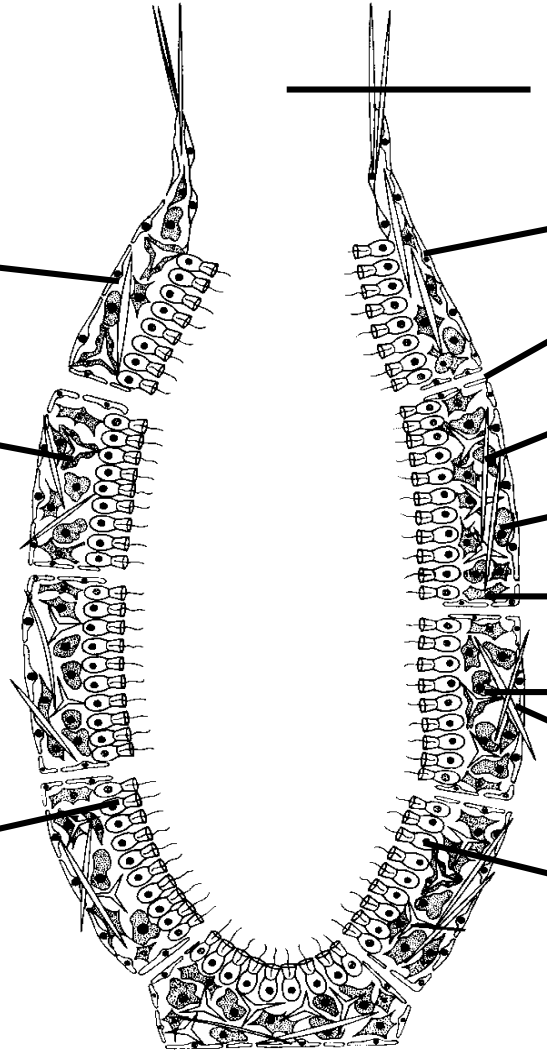
- **Blick ins Innere eines Schwammes: Epithel & Zelltypen**

3-schichtiger Aufbau:

Pinacoderm

Mesohyl

Choanoderm



Osculum

Pinacocyt

Porocyt mit Pore

Archaeocyten (totipotent)

Trophocyten (Verdauen)

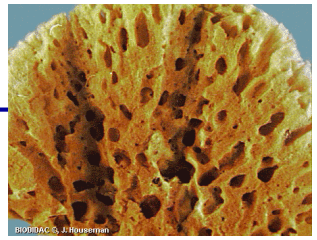
Collencyten (Gerüst)

Skleroblasten (Skelett-bildung)

Spiculae

Choanocyten

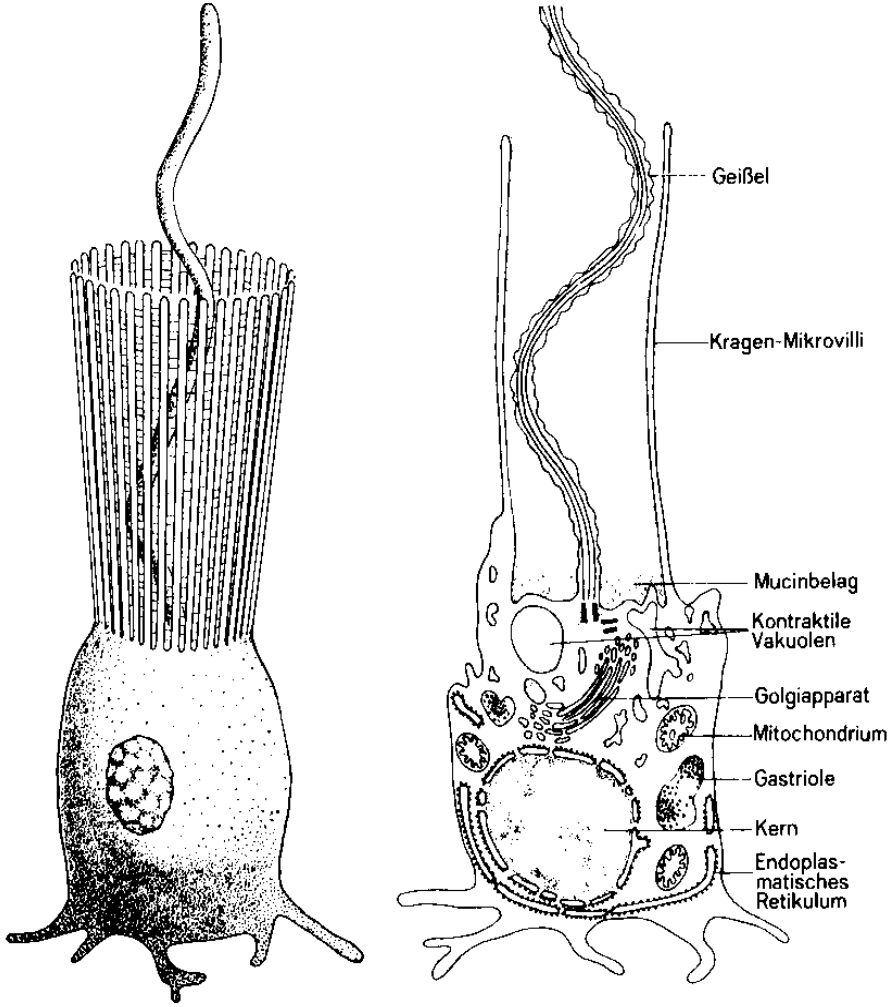
Porifera - Schwämme

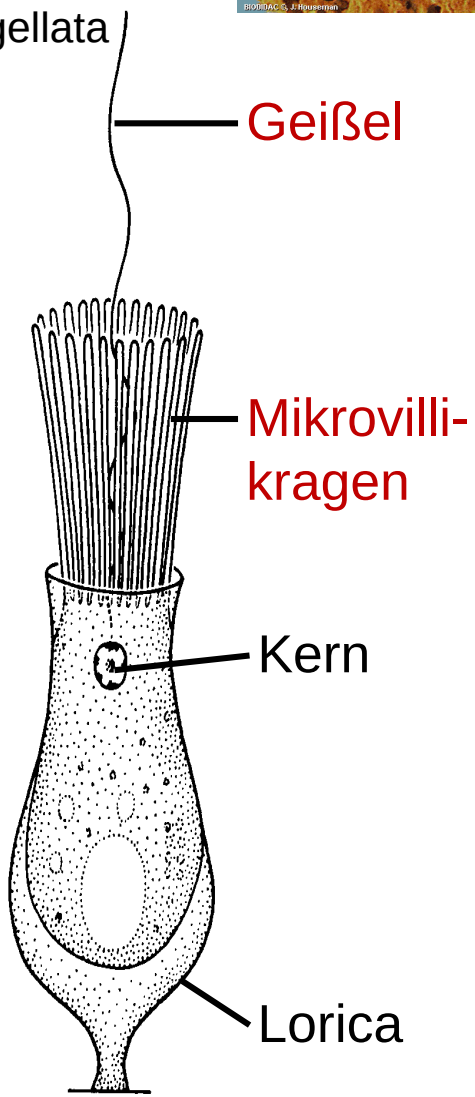


- **Kragengeißelzellen - bauen Choanoderm auf**

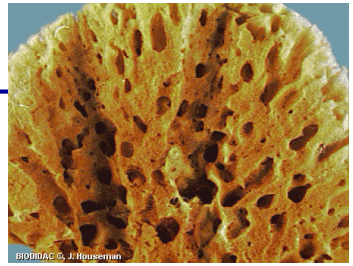
Aufbau einer Choanocyte

- erzeugen Wasserströmung & nehmen Nahrung auf



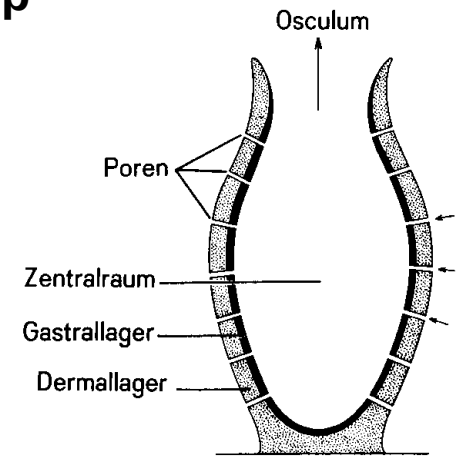


Porifera - Schwämme

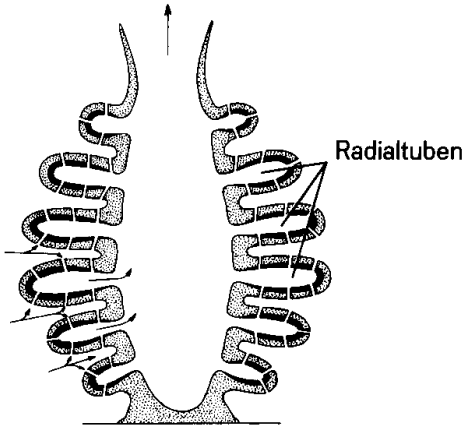


- **3 Bauplantypen: ein System von Poren & Kammern**

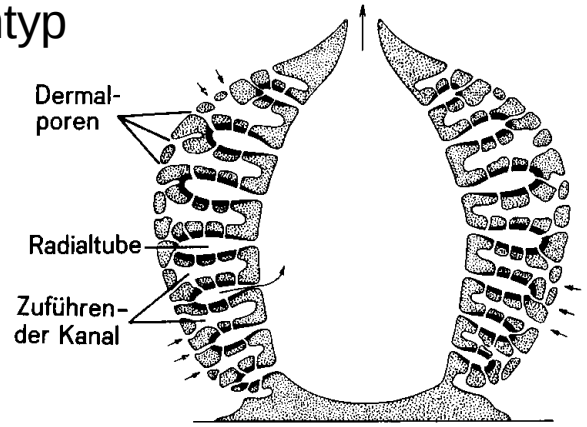
Ascontyp



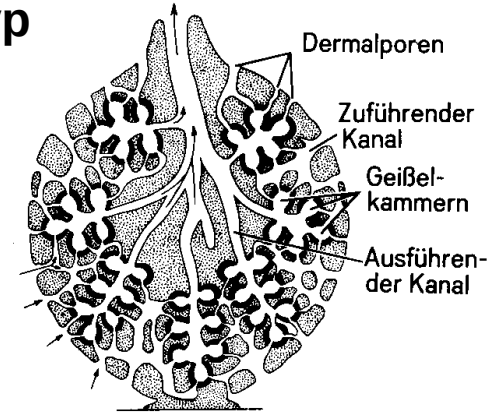
Sycontyp



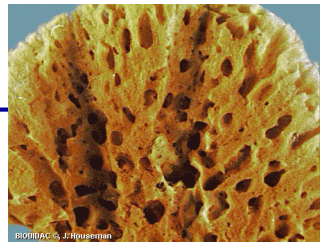
Sycontyp



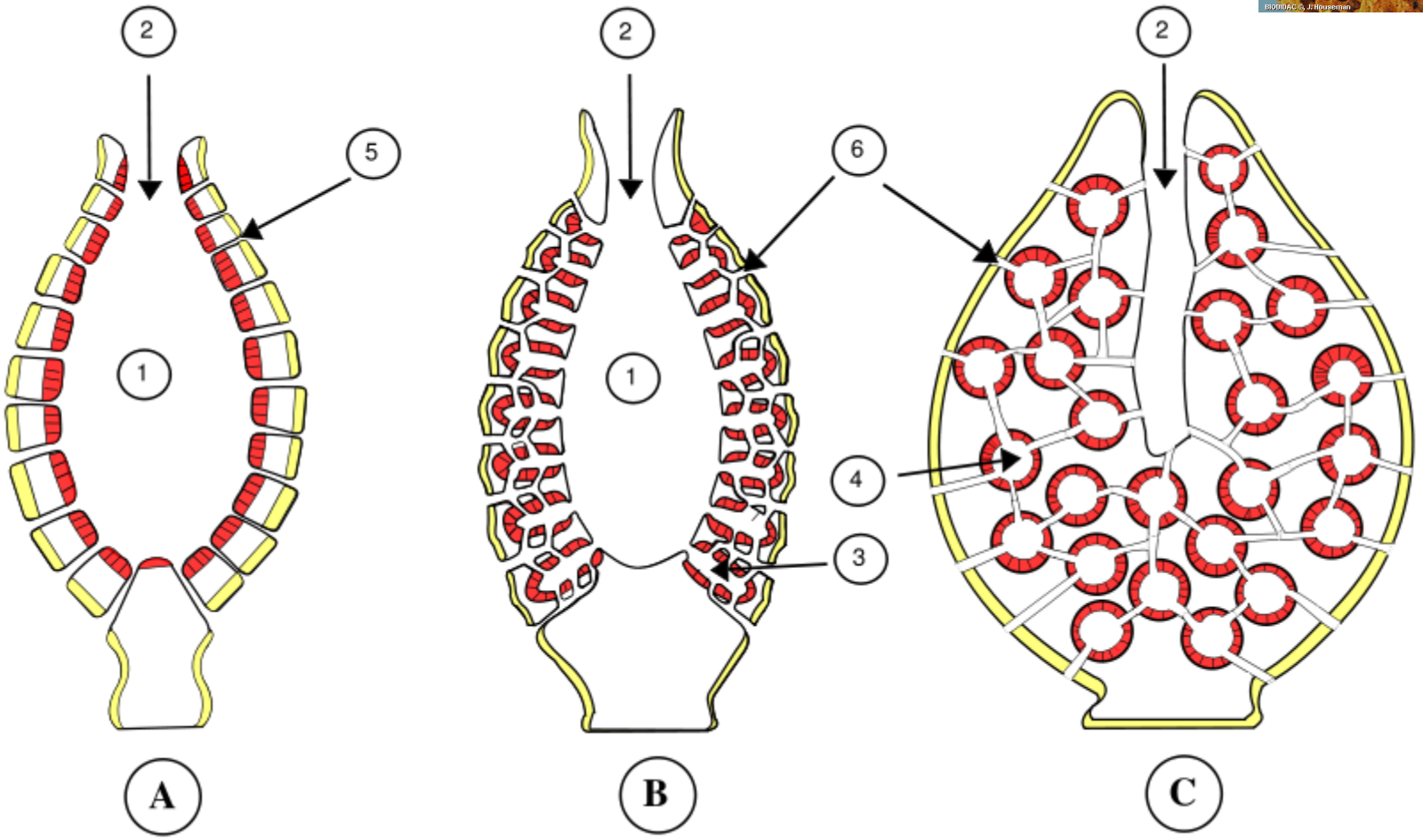
Leucontyp



Porifera - Schwämme



- **vom Zentralraum über Radialtuben zur Geißelkammer**



Ascon-Typ

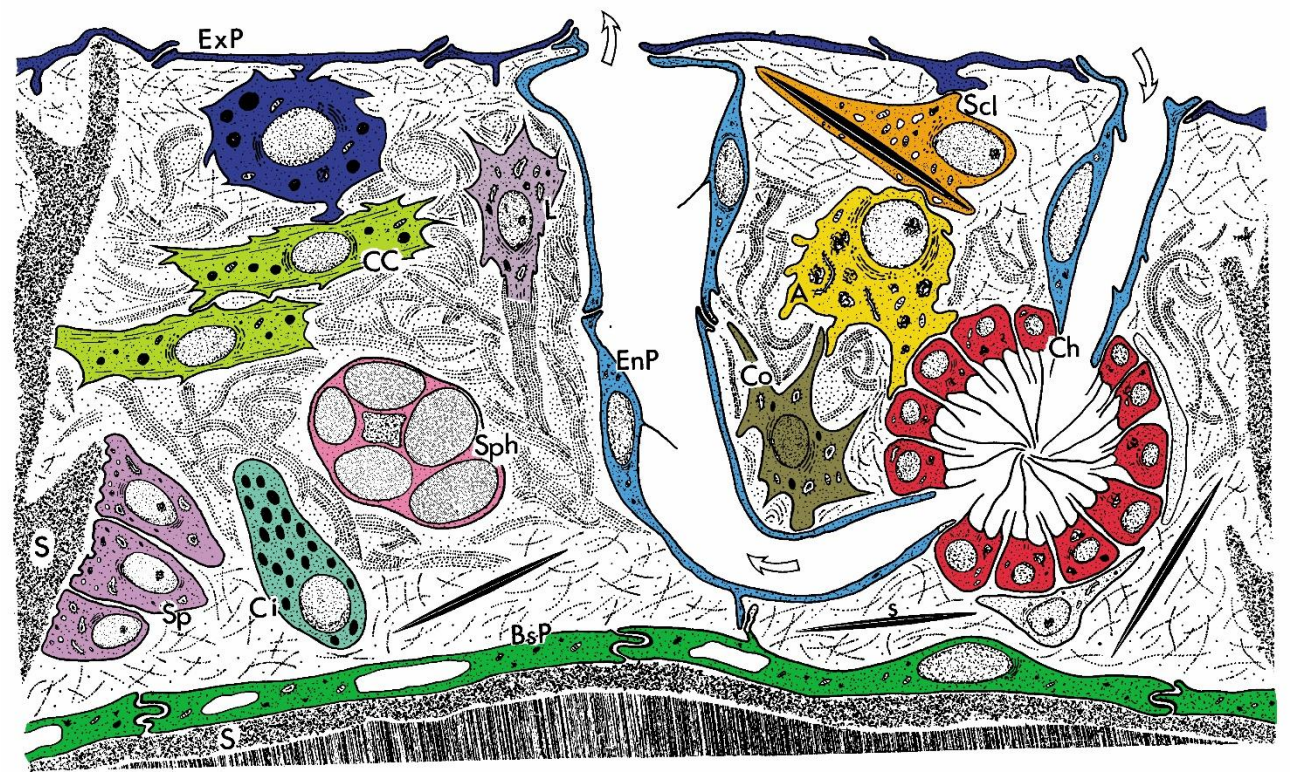
Sycon-Typ

Leucon-Typ
(>95% der Schwämme)

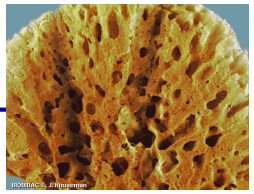
Porifera - Schwämme

- **Die wichtigsten Fakten**

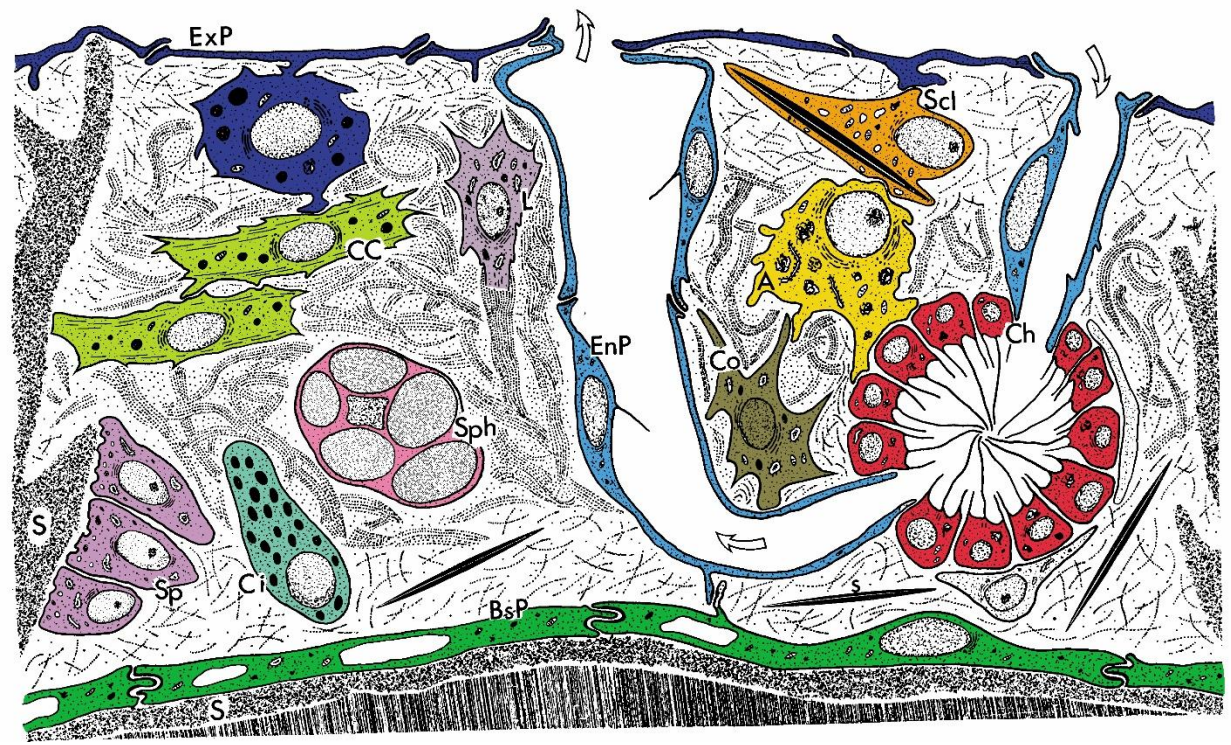
  - Schwämme besitzen keine Organe
  - Schwämme haben ein bedeckendes Epithel, das Pinakoderm
  - und im Inneren unterschiedliche Zelltypen



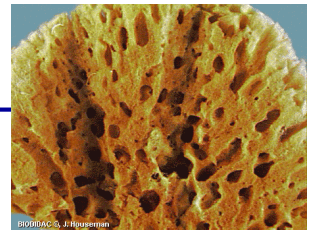
Porifera - Schwämme



- **Die wichtigsten Fakten**
  - Schwämme besitzen ein unterschiedlich komplexes Poren/Kammersystem
  - In diesem Kammersystem befinden sich Choanocyten (Zellen mit Cilien und Mikrovillikranz), die einen Wasserstrom erzeugen



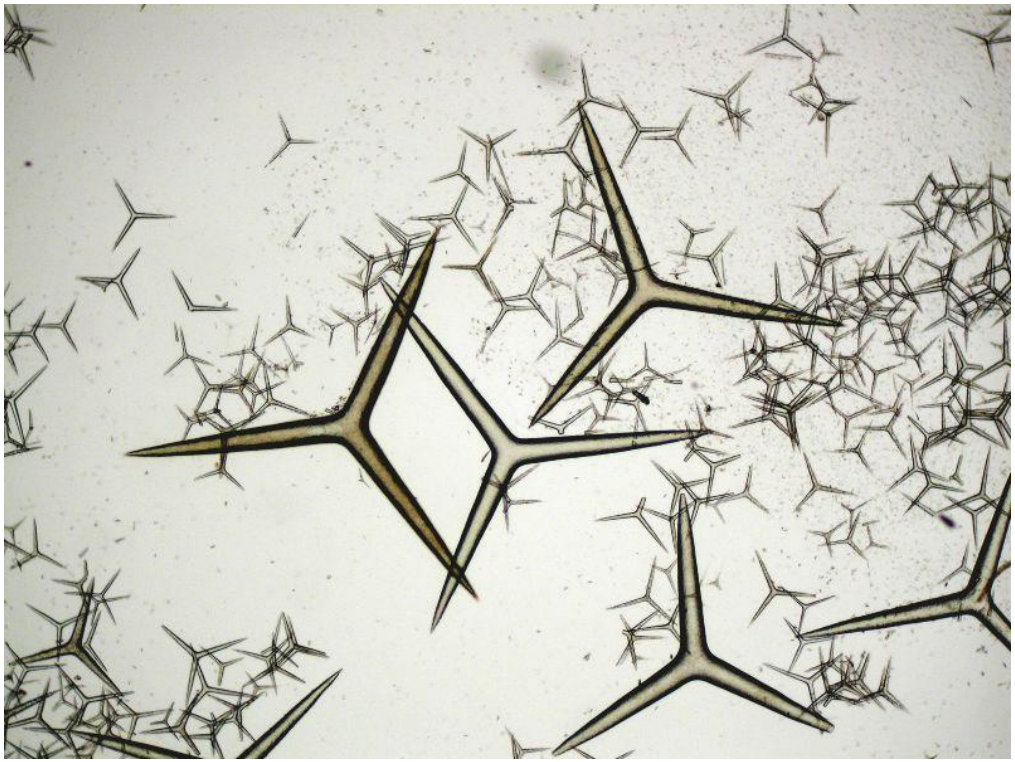
Porifera - Schwämme



- **Die wichtigsten Fakten**

  - Im Schwamminneren befinden sich Zellen, die extrazelluläre Materialien ausscheiden können und so Skelettelemente aufbauen:

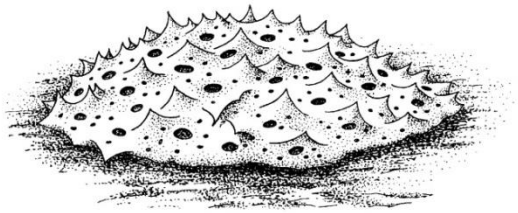
    hornige Substanzen, Kalk und Siliziumdioxyd



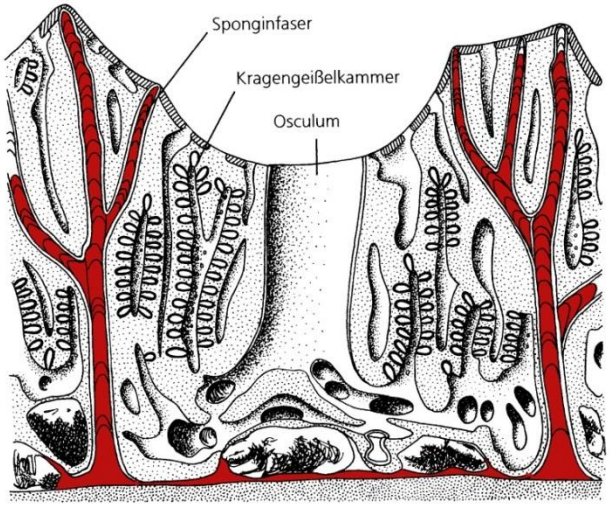
Schwammnadeln

Porifera - Schwämme

- **Spongin und Kieselnadel**

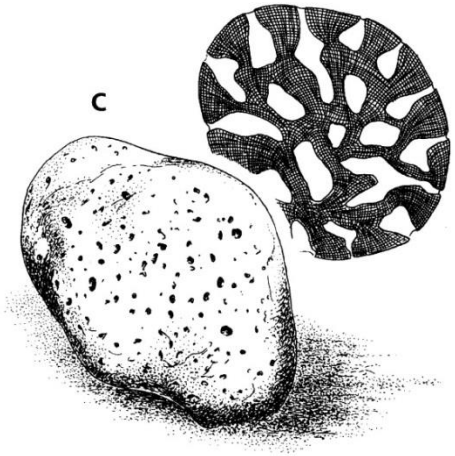


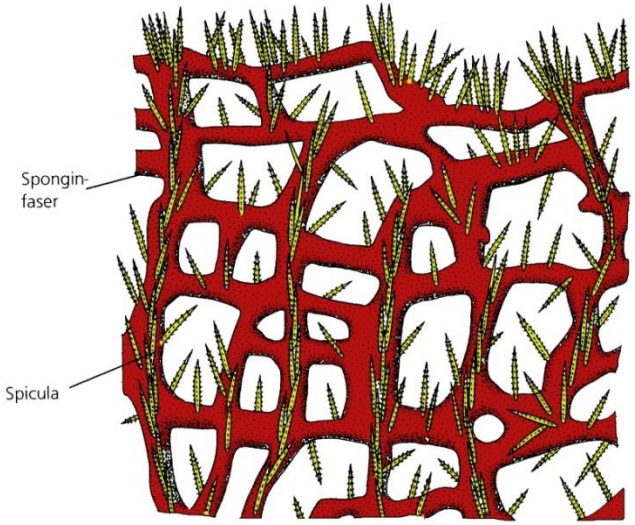
Aplysilla violacea



rot = Protein-Skelett (Spongin)

Agelas dispar





gelb = Kiesel-nadeln